CHAPTER 6
SYSTEM IMPROVEMENT PLANS

In the next ten years, exciting new technologies will be implemented to help ease air traffic congestion, add to system capacity, and enhance safety. Some of these changes will be invisible to pilots, and will be made seamlessly. Others will entail changing some old habits and learning new procedures. New aircraft equipment will bring powerful new capabilities, but will require training and practice to master.

FLEET IMPROVEMENT

Airlines and other operators will continue trying to find more efficient ways to use the National Airspace System (NAS). More and more users are working with federal agencies to write new policies and develop exchanges of real-time flight information, all in the interest of improving their service as well as their bottom lines. As new business strategies emerge, there also will be changes in the aircraft fleet. For example, as regional jets continue to increase in popularity, they have significant potential to reduce traffic at major airports as well as on the most crowded airways. Providing service along underused area navigation (RNAV) routes directly between smaller city pairs, they can bypass congested hubs and avoid airborne choke points. The number of regional jets is forecast to nearly quadruple in the next decade. Compared to the turboprop airplanes they will replace, RJs fly at similar speeds and altitudes as larger jets, so they mix into traffic streams more smoothly, making en route traffic management easier for controllers. [Figure 6-1]

Figure 6-1. Regional Jets.

At the other end of the spectrum, larger airplanes capable of carrying over 500 passengers are under development. These "superjumbos" have the potential to reduce airway and terminal congestion by transporting more people in fewer airplanes. This is especially valuable at major hubs, where the number of flight operations exceeds capacity at certain times of day. On the other hand, their double-deck configuration may require extensive changes to terminals so that large numbers of passengers can board and deplane quickly and safely. Their size may require increased separation of taxiways and hold lines from runways due to increased wing spans and tail heights. Their weight also may require stronger runways and taxiways. [Figure 6-2]

Figure 6-2. Superjumbo Airplanes.

Faster commercial airplanes are also being proposed. Flying at .95 to .98 Mach, these new airplanes would be 15-20 percent faster than conventional jetliners. Intended for longer routes, they could shave hours off intercontinental flights, although if near-sonic airplanes become popular with carriers, integrating them into existing traffic may pose new challenges for controllers. [Figure 6-3]

Figure 6-3. Faster Airplanes. Traveling at just under the speed of sound would shorten a flight from New York to Tokyo by two hours.

ELECTRONIC FLIGHT BAG

As part of an ongoing effort to use the best technology available, industry has improved the timeliness and accuracy of information available to the pilot by converting it from a paper to a digital medium. This new wireless technology designed for airline cockpits, is referred to as an electronic flight bag (EFB). Essentially a compact electronic computer optimized for use in the cockpit, the EFB uses special software and aviation databases to combine a variety of functions into one efficient package. The EFB, which exists both as a portable laptop and as a device that can be installed in an aircraft, is designed to improve efficiency and safety by providing real-time and stored data to pilots electronically. Use of an EFB can reduce some of a pilot's time-consuming communications with ground controllers while eliminating considerable weight in paper. [Figure 6-4]

Another advantage of the EFB is its capacity for performing flight calculations. For example, an airline pilot preparing for takeoff consults with ground personnel to make a series of complex calculations (factors include the number of passengers, weight of cargo, amount of fuel on board and weather conditions) that determine the proper engine settings for takeoff. Making the calculations, which give the pilot the most efficient engine settings to get the best takeoff with the least unnecessary fuel burn, takes time and if there is a sudden, last-minute change, the whole process is set back to square one, potentially delaying take-off. With today's crowded skies, that efficiency can save more than a couple of minutes. For example, if the pilot is not ready when air traffic control (ATC) says go, the pilot may be delayed up to 20 minutes before a new slot is available.

An EFB stores airport maps that can help a pilot avoid making a wrong turn on a confusing path of runways and taxiways, particularly in poor visibility or at an unfamiliar airport. Many runway incursions are due to confusion about taxi routes or pilots not being quite sure where they are on the airport. Technology can enable them to see both their cleared taxi route and the position of their aircraft as a symbol on a detailed moving map. As new technologies such as **automatic dependent surveillance broadcast (ADS-B)** gain widespread use, cockpit displays will be able to show the positions of other aircraft on the airport as well as ADS-B-equipped ground vehicles. [Figure 6-5]

Most pilots who operate under Title 14 of the Code of Federal Regulations (CFR) Part 91 do not need specific Federal Aviation Administration (FAA) approval to use EFBs as long as the unit does not replace any system or equipment required by the regulations. Those who operate under Parts 121, 125, 129, or 135, may need to obtain certification and approval. Advisory Circular (AC) 120-76, *Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Device* sets forth an acceptable means for obtaining both certification and approval for operational use of EFBs. It also outlines the capabilities and limitations of each of the three classes of EFBs, which are grouped according to purpose and function. Depending on the features of the specific unit, these devices are able to display a wide range of flight-related

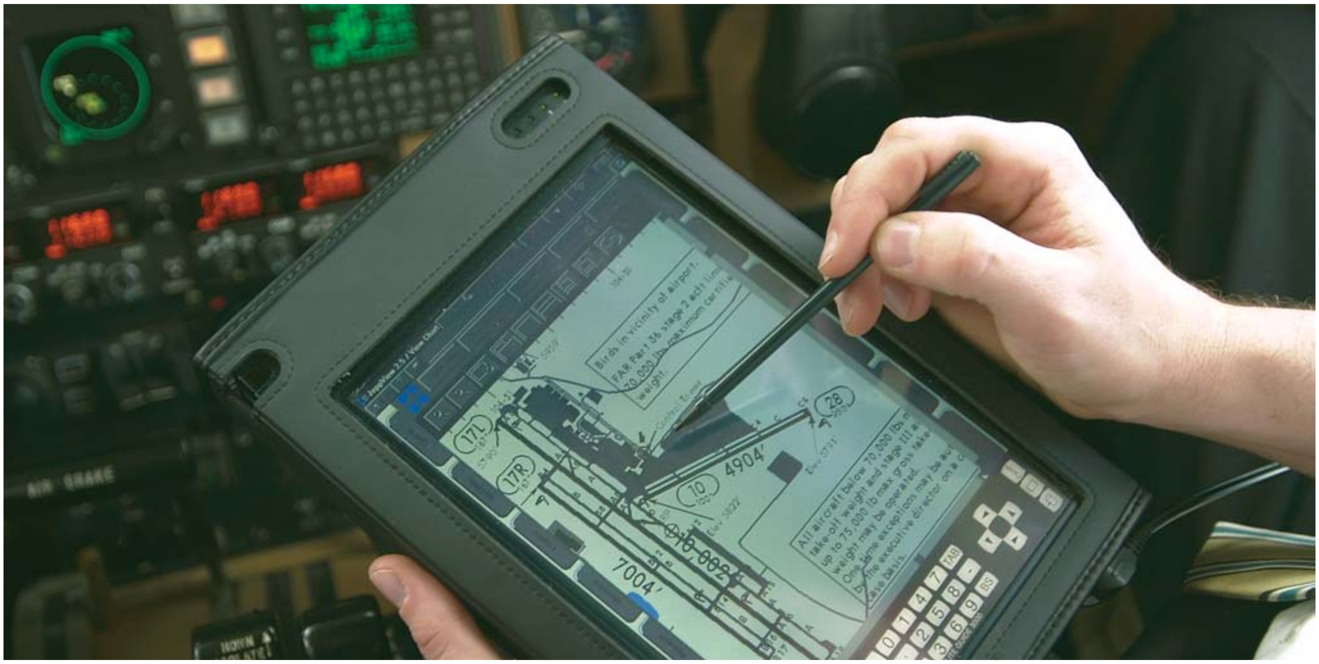

Figure 6-4. Electronic Flight Bag. The EFB has the potential to replace many paper charts and manuals in the cockpit.

information. The most capable EFBs are able to display checklists, flight operations manuals, CFRs, minimum equipment lists, en route navigation and approach charts, airport diagrams, flight plans, logbooks, and operating procedures. Besides serving as a cockpit library, they can also make performance calculations

Figure 6-5. Moving Map Taxi Diagram on EFB.

and perform many of the tasks traditionally handled by a dispatch department. Some units can also accept satellite weather data or input from global positioning system (GPS) receivers, combining the aircraft position and graphic weather information on a moving map display.

Class 1 units are completely portable. They are battery-operated and must not be connected to the aircraft in any way. The EFB can display a number of valuable reference materials, but is essentially a "read-only" resource. Consequently, it can display many different kinds of tabular data, such as performance tables, flight operations manuals (FOMs), pilot's operating handbooks/aircraft flight manuals (POHs/AFMs), and checklists, but it is not approved for interactive operations, such as performance calculations. The unit must be stowed for takeoff and landing. Class 1 EFBs are limited to providing supplemental information only and cannot replace any required system or equipment. Although it must be a stand-alone unit and must not interfere with other aircraft systems, pilots are permitted to use a cord to occasionally charge the battery from aircraft power, in the same way a laptop computer might be charged. Pilots are required to obtain appropriate training in the proper operation of the unit.

While a Class 2 EFB is also removable from the aircraft, it is installed in a structural-mounting bracket, which must have a Supplemental Type Certificate (STC). While Class 1 and 2 EFBs are considered portable electronic devices (PEDs), a logbook entry is required to remove the Class 2 EFB from the aircraft. It can be connected to aircraft power and to the aircraft's datalink port. The Class 2 EFB can exchange data with aircraft systems, enabling it to make interactive performance calculations. It can be used to compute weight and balance information as well as takeoff and landing V-speeds, and to display flight critical pre-composed data, such as navigation charts. Since it is not necessarily stowed for takeoff and landing, pilots can use it to display departure, arrival, and approach charts. The EFB can be used to eliminate some of the paper manuals and charts required to be on board the aircraft.

To use a Class 2 EFB, the Principal Operations Inspector (POI) must grant approval for a six-month evaluation period, during which both the unit and paper resources must be carried. After the evaluation period, approval must be obtained through the POI and a Flight Standardization Board Report. Depending on the requirements of the operator, paper charts and manuals may be required as a backup to the EFB. Class 2 EFBs do not require design approval from the Aircraft Certification Office, but do require approval for the power connection, datalink connectivity, and for crashworthiness of the mounting cradle.

The most capable EFBs are Class 3. These are built into the panel and require an STC or certification design approval with the aircraft as part of its equipment. Paper charts are not required. Depending on the model, it may be connected to the GPS or Flight Management System (FMS), and it may be able to combine GPS position with the locations and speed vectors of other aircraft and graphic weather information into a single, detailed moving map display. Its detailed database can also provide obstacle and terrain warnings. It is important to remember that an EFB does not replace any system or equipment required by the regulations.

INCREASING CAPACITY AND SAFETY

Safety is, and will remain, the highest priority in all plans to increase capacity for the future. As demand for air travel continues to rise, it is clear that NAS capacity must grow. Both the number of airport operations and en route capacity must increase simultaneously to accommodate the expanding needs. Neither can realistically be treated separately from the other, but for the sake of convenience, this chapter first discusses increasing the arrival/departure rate, then en route issues.

The number of aircraft operations is expected to increase by about 30 percent over the next decade. Although most parts of the NAS are able to handle current traffic, increasing operations will strain system capabilities unless capacity grows to match demand. The FAA has identified and begun to correct several existing "choke points" in the NAS. While relatively few airports and airways experience large numbers of delays, the effects snowball into disruptions throughout the rest of the system, especially in adverse weather. Capacity must be increased to manage future growth. The FAA is implementing a number of programs to increase the capacity and efficiency of the NAS. The industry itself is also taking specific actions to address some of the problems.

INCREASING THE DEPARTURE/ARRIVAL RATE

Relatively few routes and airports experience the majority of congestion and delays. In the case of airports, peak demand occurs for only a few, isolated hours each day, so even the busiest hubs are able to handle their traffic load most of the time. Adjusting the number of arrivals and departures to get rid of those peak demand times would ease congestion throughout the system.

MORE RUNWAYS

At some major hubs, adding new runways or improving existing runways can increase capacity by as much as 50 percent, but the process is complex and time-consuming.

During the planning phase, the appropriate FAA offices must review the new runway's impact on airspace, ATC procedures, navigational aids (NAVAIDs), and obstructions. New instrument procedures must be developed, and economic feasibility and risk analysis may be required.

The next phase includes land acquisition and environmental assessment. Often, the airports that most need new runways are "landlocked" by surrounding developed areas, so obtaining land can be difficult. On top of that, residents and businesses in the area sometimes resist the idea of building a new runway. Concerns range from increased noise to safety and environmental impact. While environmental assessments and impact statements are essential, they take time. The FAA is working with other federal authorities to streamline the process of obtaining permits. Good community relations are extremely important, and working with airport neighbors can often address many of the questions and concerns.

The next phase of development involves obtaining the funding. A new runway typically costs between 100 million and a billion dollars. Money comes from airport cash flow, revenue and general obligation bonds, airport improvement program grants, passenger facility charges, and state and local funding programs.

The last phase includes the actual construction of the new runway, which may take as many as three years to complete. In all, over 350 activities are necessary to commission one new runway. The FAA has created the Runway Template Action Plan to help airport authorities coordinate the process.

SURFACE TRAFFIC MANAGEMENT

In cooperation with the FAA, the National Aeronautics and Space Administration (NASA) is studying automation for aiding surface traffic management at major airport facilities. The surface management system (SMS) is an enhanced decision support tool that will help controllers and airlines manage aircraft surface traffic at busy airports, thus improving safety, efficiency, and flexibility. The SMS provides tower controllers and air carriers with accurate predictions of the future departure demand and how the situation on the airport surface, such as takeoff queues and delays at each runway, will evolve in response to that demand. To make these predictions, the SMS will use real-time surface surveillance, air carrier predictions of when each flight will want to push back, and computer software that accurately predicts how aircraft will be directed to their departure runways.

In addition to predictions, the SMS also provides advisories to help manage surface movements and departure operations. For example, the SMS advises a departure sequence to the ground and local controllers that efficiently satisfies various departure restrictions such as miles-in-trail (MIT) and expected departure clearance times (EDCTs). Information from the SMS is displayed in ATC towers and airline ramp towers, using either dedicated SMS displays or by adding information to the displays of other systems.

The system is still under development and, depending on the outcome of the research, SMS may also provide information to the terminal radar approach control (TRACON) and center traffic management units (TMUs), airline operations centers (AOCs), and ATC system command centers (ATCSCCs). By December 2003, NASA's goal is to transfer SMS to the FAA for deployment. In the future, additional developments may enable SMS to work with arrival and departure traffic management decision support tools.

Surface movement advisor (SMA) is another program now being tested in some locations. This project facilitates the sharing of information with airlines to augment decision-making regarding the surface movement of aircraft, but is concerned with arrivals rather than departures. The airlines are given automated radar terminal system (ARTS) data to help them predict an aircraft's estimated touchdown time. This enhances airline gate and ramp operations, resulting in more efficient movement of aircraft while they are on the ground.

TERMINAL AIRSPACE REDESIGN

The FAA is implementing several changes to improve efficiency within terminal airspace. While some methods increase capacity without changing existing routes and procedures, others involve redesigning portions of the airspace system. One way of increasing capacity without major procedural changes is to fill the gaps in arrival and departure streams. Traffic management advisor (TMA) is ATC software that helps controllers by automatically sequencing arriving traffic. Based on flight plans, radar data, and other information, the software computes very accurate aircraft trajectories as much as an hour before the aircraft arrives at the TRACON. It can potentially increase operational capacity by three to ten percent.

One limitation of TMA is that it uses information on incoming flights from a single ARTCC. Another version is under development that will integrate information from more than one ARTCC. It is called multi-center traffic management advisor (McTMA).

Another software-based solution is the passive final approach spacing tool (pFAST). This software analyzes the arriving traffic at a TRACON and suggests appropriate runway assignment and landing sequence numbers to the controller. Controllers can accept or reject the advisories using their keyboards. The early version carries the "passive" designation because it provides only runway and sequence number advisories. A more advanced version, called active FAST, is currently under development at NASA Ames Research Center. In addition to the information provided by pFAST, it will display heading, speed, and turn advisories.

Airlines can help ease congestion on shorter routes by filing for lower altitudes. Although the airplane uses more fuel at a lower cruising altitude, the flight may prove faster and more economical if weather or high traffic volume is delaying flights at higher levels. The tactical altitude assignment program consists of published routes from hubs to airports 200 to 400 nautical miles (NM) away. Based on results of evaluation, it is not expected to be implemented nationally; although it may remain available in local areas.

Beyond using existing facilities and procedures more effectively, capacity can often be increased by making relatively minor changes in air traffic procedures. For example, in some instances, departure and arrival patterns have remained unchanged from when there was very little air traffic, and congestion results when today's traffic tries to use them. Likewise, arrival and departure procedures may overlap, either because they were based on lower volumes and staffing or because they are based on ground-based navigation. The interdependence of arrival and departure routes tends to limit throughput in both directions.

Separating departures from incoming traffic can simplify the work of controllers, reduce vectoring, and make more efficient use of terminal airspace. In the **four corner post configuration**, four NAVAIDs form the four corners of the TRACON area, roughly 60 NM from the primary airport. All arrivals to the area fly over one of these "corner posts" (also called arrival meters or feeder fixes). The outbound departure streams are spaced between the arrival streams. [Figure 6-6]

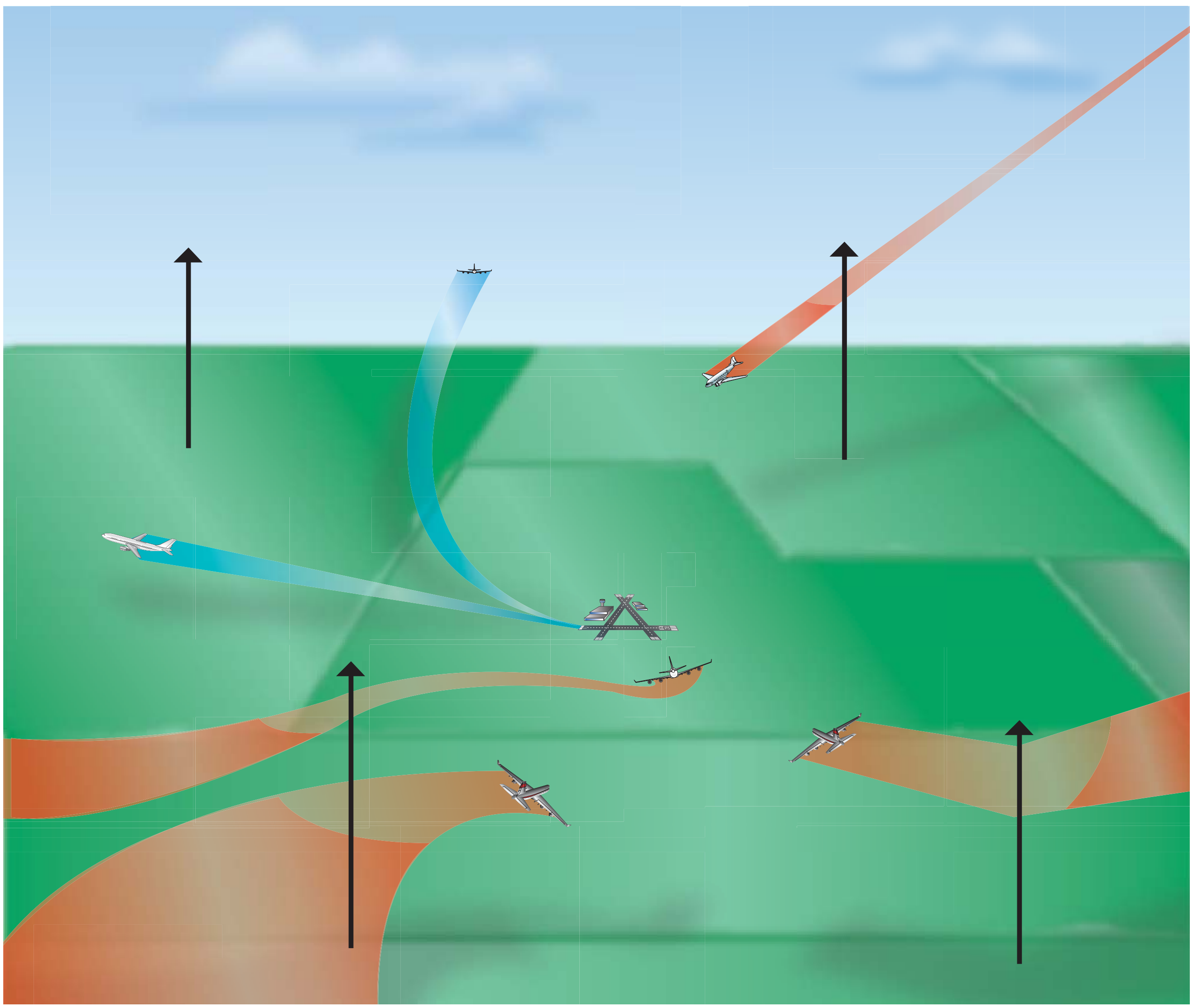

Figure 6-6. Four Corner Post Configuration.

As more and more aircraft are equipped for RNAV, new arrival and departure routes are being created that do not depend on very high frequency omni-directional range (VOR) airways or ground-based NAVAIDs. Shifting traffic to new RNAV routes eases congestion on existing airways. There are already several new RNAV routes in use and many more are being developed.

SEPARATION STANDARDS

Current regulations permit a 3 NM separation within 40 NM of a single radar sensor. The FAA is looking at ways to increase the use of the 3 NM separation standard to improve efficiency and maximize the volume of traffic that can be safely moved into busy terminal areas. The methods involve increasing the size of terminal areas to include more en route airspace, redesigning airspace to encompass multiple airports within a single ATC facility, and consolidating certain TRACON facilities. This will involve major changes on the ground for ATC facilities, and changes in charts and procedures for pilots.

As gaps are filled in arrival and departure streams and the 3 NM separation standard is applied more extensively, traffic advisories from the traffic alert and collision avoidance system (TCAS) are bound to increase. While newer software enhances functionality, provides more timely resolution advisories, and eliminates many nuisance alerts, datalink technology based on GPS position information may offer even better results.

MAINTAINING RUNWAY USE IN REDUCED VISIBILITY

Although traffic in congested airspace typically operates under instrument flight rules (IFR), adverse weather and actual instrument meteorological conditions (IMC) can drastically reduce system capacity. Many parallel runways cannot be used simultaneously in IMC because of the time delay and limited accuracy of terminal area radar, and are spaced closer than the minimum allowable distance of 4,300 feet for wake vortex separation.

LAAS AND WAAS IMPLEMENTATION

The two systems being developed to improve GPS position accuracy and availability for instrument approaches will also help keep additional runways open in adverse weather. The wide area augmentation system (WAAS) became available at some locations in 2003. The local area augmentation system (LAAS) provides even greater accuracy and is due to be certified for use in Category I approaches at some locations around 2005.

Another benefit of LAAS and WAAS is that better position information can be sent to controllers and other aircraft. ADS-B uses GPS to provide much more accurate location information than radar and transponder systems. This position information is broadcast to other ADS-equipped aircraft (as well as ground facilities), providing pilots and controllers with a more accurate real-time picture of traffic. Cockpit displays can warn of conflicts, show nearby traffic, and perhaps allow pilots to work out their own conflict resolution. This will permit the basic idea of TCAS to be carried to a much more practical level.

For full safety and effectiveness, every aircraft under the control of ATC would need ADS-B. Until that occurs, controllers must deal with a mix of ADS-B and transponder-equipped aircraft. Equipment is already available that can fuse the information from both sources and show it on the same display. **Traffic information service-broadcast (TIS-B)** does just that. Although TIS-B is primarily intended for use on the ground by controllers, the information can be transmitted to suitably equipped aircraft and displayed to pilots in the cockpit. The **cockpit display of traffic information (CDTI)** provides information on ADS-B and non-ADS-B aircraft on a single cockpit display. [Figure 6-7 on page 6-8] Since this information is shown even while the aircraft is on the ground, it also improves situational awareness during surface movement, and can help prevent or resolve taxiing conflicts.

PRECISION RUNWAY MONITOR

One of the limitations of conventional terminal approach radar is that aircraft positions are updated on the controller's scope only once every five seconds. The precision runway monitor (PRM) system consists of electronic high update radar and a high resolution ATC radar display that is updated once per second. While typical terminal approach radar sweeps the entire area around the airport, PRM is aligned with the centerline of the runway it serves and can resolve targets 60 feet apart at a range of 32 NM, although normally it is not authorized beyond 10 NM from the runway. Because of these capabilities, PRM allows parallel runways that are too close together to meet normal operational standards to be used for simultaneous approaches in IMC. PRM systems have been installed at several locations, and more are expected to be commissioned in the next few years, helping to increase capacity at major airports. PRM requires special training and for some locations may require monitoring two separate tower frequencies simultaneously.

OFFSET FINAL APPROACH PATH

Simultaneous offset instrument approaches (SOIA) allow the use of parallel runways as little as 750 feet apart for approaches in IMC. To be approved for these operations, each runway must have PRM and a separate instrument landing system (ILS) (or localizer-type direction aid [LDA] with glide slope). One ILS is aligned with one of the runways, but the other is angled a few degrees off from the other runway's centerline.

Figure 6-7. Cockpit Display of Traffic Information. This display shows both ADS-B and other aircraft radar targets.

This serves to increase separation until the aircraft acquire each other visually. [Figure 6-8]

REDUCING EN ROUTE CONGESTION

In addition to the congestion experienced at major hubs and terminal areas, certain parts of the en route structure have reached capacity. Easing the burden on high-volume airways and eliminating airborne choke points are some of the challenges addressed by new airspace plans.

MATCHING AIRSPACE DESIGN TO DEMANDS

New RNAV routes are being created, which are essentially airways that use RNAV for guidance instead of VORs. They are straighter than the old VOR airways, so they save flight time and fuel costs. By creating additional routes, they reduce traffic on existing airways, adding en route capacity. As new routes are created near existing airways, chart clutter may become more of an issue. Electronic chart presentations are being developed that will allow pilots to suppress

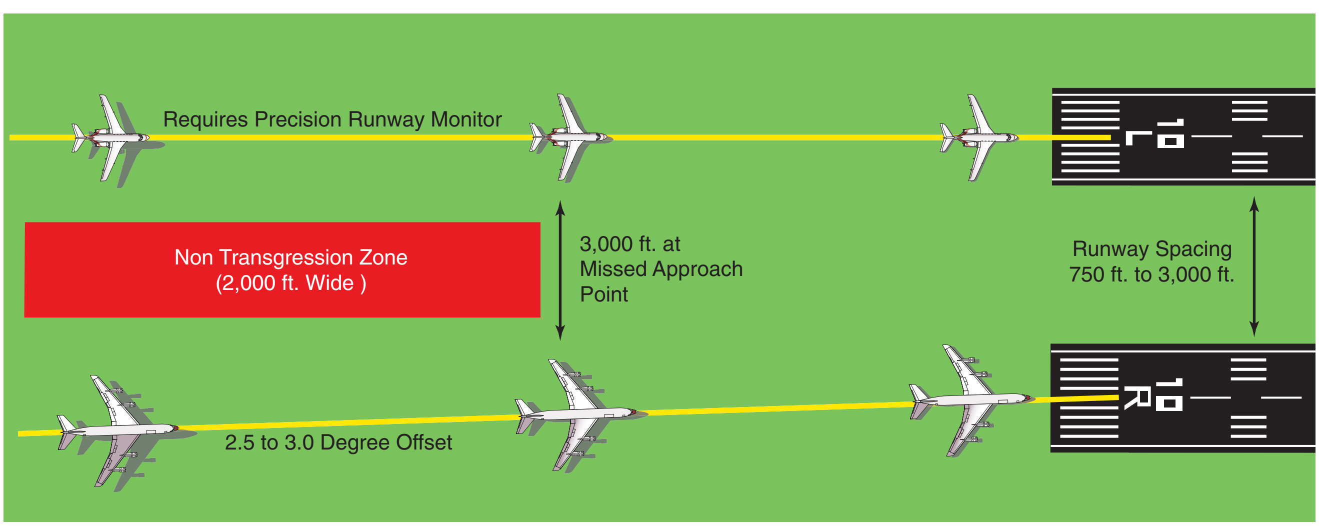

Figure 6-8. Offset Final Approach Path.

information that is irrelevant to their flight, while ensuring that all information necessary for safety is displayed.

REDUCING VOICE COMMUNICATION

Many runway incursions and airborne clearance mistakes are due to misunderstood voice communications. During busy periods, the necessity of exchanging dozens of detailed instructions and reports leads pilots and controllers to shorten and abbreviate standard phraseology, often leading to errors. It stands to reason that better ways to transfer information could reduce voice communications, and thus reduce the incidence of communication errors. One such innovation is similar to the display screen at fast-food drive-up windows. As the cashier punches in the order, it is displayed on the monitor so the customer can verify the order. This kind of feedback reduces the common problem of hearing what is expected to be heard, which is particularly problematic in ATC clearances and read backs. Not only does reducing voice communications reduce frequency congestion, but it also eliminates certain opportunities for misunderstanding.

Controller pilot data link communication (CPDLC) augments voice communications by providing a second communications channel for use by the pilot and controller, using data messages that are displayed in the cockpit. This reduces delays resulting from congestion on voice channels. The initial version of CPDLC will display a limited number of air traffic messages, but future versions will have expanded message capabilities and permit pilot-initiated requests.

AIRCRAFT COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM

Of course, pilot-controller communication is compromised when the crew is listening to other frequencies or engaged in other communications, such as talking to their company. If these communications could be accomplished silently and digitally, voice communications with ATC would improve. The Aircraft Communications Addressing and Reporting System (ACARS) is a commercial system that enables the crew to communicate with company personnel on the ground. It is often used to exchange routine flight status messages, weather information, and can serve as a non-voice communication channel in the event of an emergency. Many of the messages are sent and received automatically, such as the time the flight leaves the gate (triggered by the release of the parking brake), takeoff and touchdown times (triggered by landing gear switches), and arrival time (triggered when a cabin door is opened). Other information may include flight plans, significant meteorological information (SIGMETs), crew lists, cargo manifests, automatic terminal information service (ATIS) reports, en route and destination weather, clearances, and fuel reports. Some ACARS units can interface with onboard engine and performance monitoring systems to inform company ground personnel of maintenance or operations related issues. [Figure 6-9]

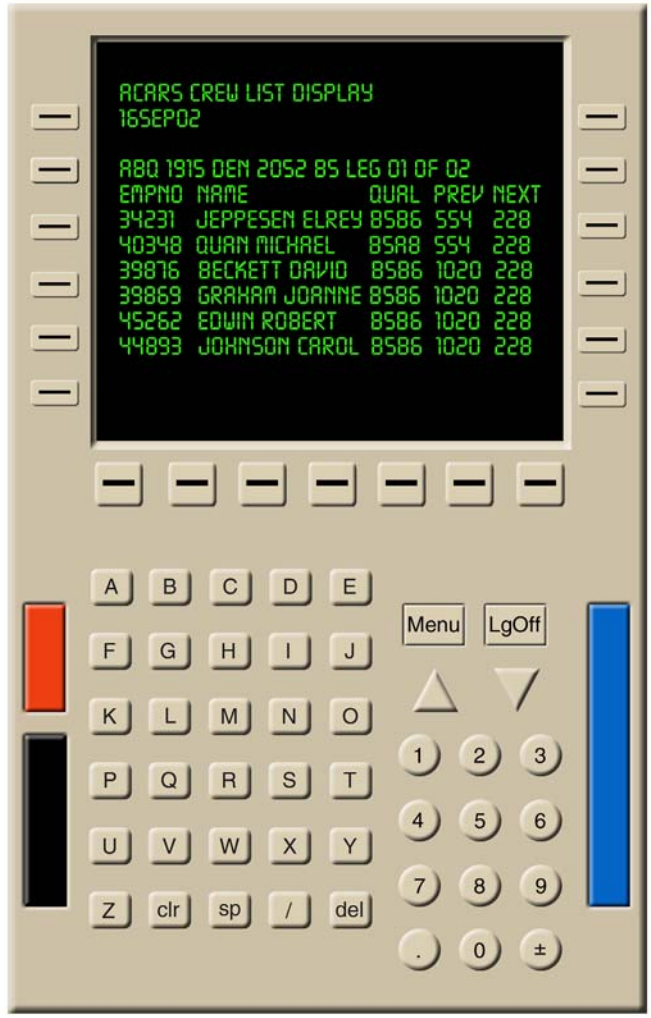

Figure 6-9. ACARS Communications Display.

Significant valuable meteorological data can be obtained by collecting data from aircraft fitted with appropriate software packages. To date, the predominant sources of automated aviation data have been from aircraft equipped with aircraft to satellite data relay (ASDAR) and ACARS, which routes data back via general purpose information processing and transmitting systems now fitted to many commercial aircraft. These systems offer the potential for a vast increase in the provision of aircraft observations of wind and temperature. Making an increasingly important contribution to the observational database, it is envisioned that ACARS data will inevitably supersede manual pilot reports (PIREPS).

Another use of ACARS is in conjunction with Digital ATIS (D-ATIS), which provides an automated process for the assembly and transmission of ATIS messages. ACARS enables audio messages to be displayed in text form in the flight decks of aircraft equipped with

ACARS. A printout is also provided if the aircraft is equipped with an on-board printer. D-ATIS is operational at over 57 airports that now have pre-departure clearance (PDC) capability.

AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST

Unlike traffic alert and collision avoidance systems (TCAS) and terrain awareness and warning systems (TAWS), which have been used in airline and military aircraft for at least a decade, automatic dependent surveillance-broadcast (ADS-B) is a new air traffic technology. It is an onboard system that uses Mode S transponder technology to periodically broadcast an aircraft's position, and some supporting information like aircraft identification and short-term intent. By picking up broadcast position information on the ground instead of using ground radar stations, ADS-B represents a significant advancement over the existing ATC system by providing increased accuracy and safety. This is possible because ADS-B addresses the major deficiency of TCAS — accuracy. In the TCAS system, aircraft positions are only accurate to a few degrees; thus, the accuracy of TCAS decreases with distance. Moreover, the reliance on transmission timing for range data in TCAS is error-prone. The method used by ADS-B avoids this problem.

In addition to the broadcast of position to the ground, ADS-B could be used to enable a new collection of aircraft-based applications. ADS-B will also enable aircraft to send messages to each other to provide surveillance and collision avoidance through datalink. Position information broadcasts by equipped aircraft can be picked up by other aircraft in the immediate vicinity. This enables equipped aircraft to formulate a display of proximate aircraft for the pilot; the pilot's awareness of the current situation is enhanced. Combined with databases of current maps and charts, the onboard displays could show terrain as well as proximate aircraft. This is a powerful inducement for change. The heightened situational awareness offered by satellite navigation in conjunction with modern database applications and map displays, combined with the position of proximate aircraft, builds a picture in the cockpit equivalent to that on the ground used by the controller. This is particularly important in places like Alaska where aviation is vital, NAS infrastructure is minimal (because of the harsh conditions), and weather changes quickly and in unpredictable fashions.

Eventually, as the fleets equip, it may be possible to save money by retiring expensive long-range radars. Identified by the FAA as the future model for ATC, ADS-B is a major step in the direction of free flight. While ADS-B shows great promise for both air-to-air and air-to-ground surveillance, current aircraft transponders will continue to support surveillance operations in the NAS for the foreseeable future. If enough users equip with ADS-B avionics, the FAA will install a compatible ADS ground system to provide more accurate surveillance information to ATC compared to radar-based surveillance.

MODE S EXTENDED SQUITTER

Also known as the GPS squitter, the Mode S extended squitter is a component of ADS-B that represents a smooth upgrade from traditional Mode S. A participating aircraft broadcasts ("squits") positional information using a modified Mode S transponder. The positional information comes from a source of global navigation, such as a GPS receiver. Whereas the conventional Mode S squitter just broadcasts altitude, the GPS squitter transmits information as derived from GPS. The Mode S extended squitter was demonstrated by the FAA in Boston and the Gulf of Mexico in 1994, and is being considered for ADS-B.

REDUCING VERTICAL SEPARATION

Current vertical separation minima (2,000 feet) were created more than 40 years ago when altimeters were not very accurate above FL 290. With better flight and navigation instruments, vertical separation has been safely reduced to 1,000 feet in many parts of the world.

Reduced vertical separation minimum (RVSM) airspace has already been implemented over the Atlantic and Pacific Oceans, South China Sea, Australia, and Europe. The Middle East and Asia south of the Himalayas will follow in 2003. Domestic RVSM (DRVSM) in the United States (except in Hawaii) is slated to begin in January 2005 when FL 300, 320, 340, 360, 380, and 400 will be added to the existing structure. [Figure 6-10]

To fly at any of the flight levels from FL 290 to FL 410, aircraft and operator must be RVSM-approved. Less than a quarter of the airplanes that currently operate above FL 290 are approved for RVSM operations, but these numbers are expected to increase.

REDUCING HORIZONTAL SEPARATION

The current oceanic air traffic control system uses filed flight plans and position reports to track an aircraft's progress and ensure separation. Pilots send position reports by high frequency (HF) radio through a private radio service that then relays the messages to the air traffic control system. Position reports are made at intervals of approximately one hour. HF radio communication is subject to interference and disruption. Further delay is added as radio operators relay messages between pilots and controllers. These deficiencies in communications and surveillance have necessitated larger horizontal separation minimums when flying over the ocean out of radar range.

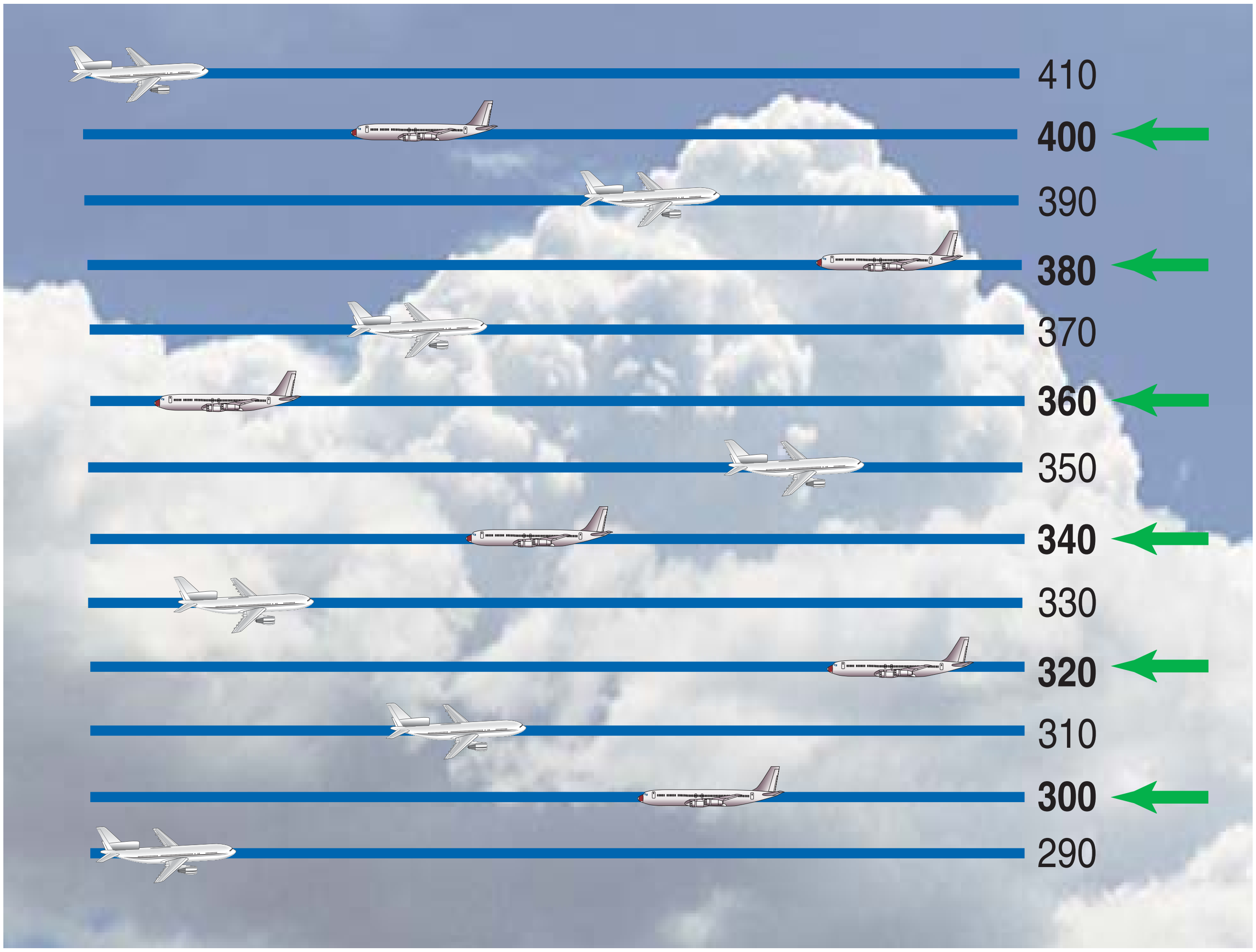

Figure 6-10. DRVSM High Altitude Routes.

As a result of improved navigational capabilities made possible by technologies such as GPS and CPDLC, both lateral and longitudinal oceanic horizontal separation standards are being reduced. Oceanic lateral separation standards were reduced from 100 to 50 NM in the Northern and Central Pacific regions in 1998 and in the Central East Pacific in 2000. The FAA plans to extend the 50 NM separation standard to the South Pacific. Because flight times along the South Pacific routes often exceed 15 hours, the fuel and time savings resulting from more airplanes flying closer to the ideal wind route in this region are expected to be substantial. Separation may be further reduced to 30 NM in parts of the South Pacific airspace by 2006 for airplanes with CPDLC, ADS-B, and required navigation performance (RNP) 4 approval.

DIRECT ROUTING

Based on preliminary evaluations, the FAA research has found evidence for tremendous potential for the airlines to benefit from expected routing initiatives. Specifically, direct routing or "free flight" is among the most promising for reducing total flight time and distance as well as minimizing congestion on heavily traveled airways. Traditionally, pilots fly fixed routes that often are less direct due to their dependence on ground-based NAVAIDs. Through free flight, the FAA hopes to increase the capacity, efficiency, and safety of the NAS to meet growing demand as well as enhance the controller's productivity. The aviation industry, particularly the airlines, is seeking to shorten flight times and reduce fuel consumption. According to the FAA's preliminary estimates, the benefits to the flying public and the aviation industry could reach into the billions of dollars once the program is fully operational.

The National Civil Aviation Review Commission warned of impending gridlock at many of our major airports, with airlines expecting to run into difficulties scheduling their flights without undue delays as early as 2005. With that in mind, the U.S. began to implement tools, through a project called Free Flight Phase 1, that help prevent gridlock while expanding airspace capabilities and accommodating growing demand. Free Flight Phase 1, using the five tools listed in figure 6-11 on page 6-12, provides the incremental steps for modernizing the NAS.

Present Position (PPOS) Direct Routing

Courtesy of Universal Avionics Systems Corporation

1. The User Request and Evaluation Tool (URET) is designed to help en route controllers predict the future flight path and identify potential conflicts. This tool helps controllers to allow aircraft to deviate from filed routes to avoid poor weather or to take advantage of favorable winds.

2. The Traffic Management Advisor (TMA) assists traffic management specialists with developing arrival sequence plans for selected airports. Currently this tool is effective at airports that receive airplanes from selected air route traffic control centers (ARTCCs).

Both URET and TMA, initiatives included in the first phase the FAA's free flight plan, will provide key improvements and are being implemented on a limited scale. These tools will help the aircraft fly a more direct route from point to point and operate on the new en route displays.

3. Collaborative Decision-Making (CDM) provides airline operation centers with real-time access to information about the status of the NAS, including information about weather, equipment status, and known delays. With this information, airlines are able to better anticipate "trouble spots" and start preparing contingency plans. Although this may not prevent a passenger from being delayed by poor weather at their destination, it does help airlines avoid stranding passengers and airplanes.

   Improving operations around the airport is critical to most major airlines. The last two tools work with the terminal automation systems and are currently being tested to improve traffic flow around airports.

4. The Passive Final Approach Spacing Tool (pFAST), used at TRACONs, helps controllers sequence aircraft and assign runways based on user preferences and airport constraints.

5. Surface Movement Advisor (SMA) improves operations near the airport by increasing the sharing of information between the FAA and the airlines. The purpose of this tool is to provide information about arriving and departing aircraft to the airlines. Information, such as identifying the runway and the sequence for landing, enables the airlines to plan better. This is most critical at hub airports when airplane turn-around times at the gate are closely scheduled.

Figure 6-11. Free Flight.

ACCOMMODATING USER PREFERRED ROUTING

Free flight phase 2 builds on the successes of free flight phase 1 to improve safety and efficiency within the NAS. Implementation of phase 2 will include the expansion of phase 1 elements to additional FAA facilities. This program will deploy a number of additional capabilities, such as collaborative decision making (CDM) with collaborative routing coordination tool enhancements and controller pilot data link communication.

CDM allows airspace users and the FAA to share information, enabling the best use of available resources. The National Airspace System status information (NASSI) tool is the most recent CDM element to be introduced. NASSI enables the real-time sharing of a wide variety of information about the operational status of the NAS. Much of this information has previously been unavailable to most airspace users. NASSI currently includes information on maintenance status and runway visual range at over 30 airports.

The collaborative routing coordination tool (CRCT) is a set of automation capabilities that can evaluate the impact of traffic flow management re-routing strategies. The major focus of this tool is management of en route congestion.

IMPROVING ACCESS TO SPECIAL USE AIRSPACE

Special use airspace (SUA) includes prohibited, restricted, warning, and alert areas, as well as military operations areas (MOAs), controlled firing areas, and national security areas. The FAA and the Department of Defense are working together to make maximum use of SUA by opening these areas to civilian traffic when they are not being used by the military. The **military airspace management system (MAMS)** keeps an extensive database of information on the historical use of SUA, as well as schedules describing when each area is expected to be active. MAMS transmits this data to the **special use airspace management system (SAMS)**, an FAA program that provides current and scheduled status information on SUA to civilian users. The two systems work together to ensure that the FAA and system users have current information on a daily basis. This information is made available through the Internet.

A prototype system called SUA in-flight service enhancement (SUA/ISE) provides graphic, near-real-time depictions of SUA to automated flight service station (AFSS) specialists who can use the information to help pilots during flight planning as well as during flight. Pronounced "Suzy," this tool can display individual aircraft on visual flight rule (VFR) flight plans (with data blocks), plot routes of flight, identify active SUA and display weather radar echoes. Using information from the enhanced traffic management system, AFSS specialists will see this information on a combined graphic display (CGD). This data may also be transmitted and shown on cockpit displays in general and commercial aviation aircraft.

The central altitude reservation function (CARF) coordinates military, war plans, and national security use of the NAS. While SAMS handles the schedule information regarding fixed or charted SUA, CARF handles unscheduled time and altitude reservations. Both subsystems deal with planning and tracking the military's use of the NAS.

The FAA and the U.S. Navy have been working together to allow civilian use of offshore warning areas. When adverse weather prevents the use of normal air routes along the eastern seaboard, congestion and delays can result as flights are diverted to the remaining airways. When offshore warning areas are not in use by the Navy, the airspace could be used to ease the demand on inland airways. To facilitate the use of this airspace, the FAA established waypoints in offshore airspace along four routes for conducting point-to-point navigation when the Navy has released that airspace to the FAA. The waypoints take advantage of RNAV capabilities and provide better demarcation of airspace boundaries, resulting in more flexible release of airspace in response to changing weather. These new offshore routes, which stretch from northern Florida to Maine, are an excellent example of how close coordination between military and civil authorities can maximize the utility of limited airspace.

HANDLING EN ROUTE SEVERE WEATHER

Interpreting written or spoken weather information is not difficult, nor is visualizing the relationship of the weather to the aircraft's route, although verbal or textual descriptions of weather have inevitable limitations. Color graphics can show more detail and convey more information, but obtaining them in flight has been impractical so far. Until recently, cockpit graphic weather displays were limited to what could be detected by sensors onboard the aircraft, such as weather radar. The graphical weather service (GWS) provides a real-time nationwide precipitation mosaic, which is transmitted to the aircraft and displayed in the cockpit. Pilots can select any portion of the nationwide mosaic with range options of 25, 50, 100, and 200 NM. In addition to providing information on precipitation, this service can be expanded to include other graphical data. This service is being demonstrated in Frederick, Maryland airspace using the commissioned Mode S sensor at Washington Dulles International Airport. The demonstration is being conducted with the participation of aircraft provided by the Aircraft Owners and Pilots Association (AOPA) using prototype commercial avionics. Other systems are being developed that will place the detailed weather graphics directly on a moving map display, removing another step of interpretation and enabling pilots to see the weather in relation to their flight path. [Figure 6-12]

Figure 6-12. Prototype Data Link Equipment. This display shows a radar image of weather within 50 NM of the Seattle-Tacoma International Airport (KSEA).

DEVELOPING TECHNOLOGY

Head-up displays (HUDs) grew out of the reflector gun sights used in fighter airplanes before World War II. The early devices functioned by projecting light onto a slanted piece of glass above the instrument panel, between the pilot and the windscreen. At first, the display was simply a dot showing where bullets would go, surrounded by circles or dots to help the pilot determine the range to the target. By the 1970s, the gun sight had become a complete display of flight information. By showing airspeed, altitude, heading, and aircraft attitude on the HUD glass, pilots were able to keep their eyes outside the cockpit more of the time. Collimators make the image on the glass appear to be far out in front of the aircraft, so that the pilot need not change eye focus to view the relatively nearby HUD. Today's systems are now referred to as Head-up Guidance Systems (HGS) and have holographic displays. Everything from weapons status to approach information can be shown on current military HGS displays. This technology has obvious value for civilian aviation, but until 1993 no civilian HGS systems were available. This is changing, and application of HGS technology in airline and corporate aircraft is becoming widespread. [Figure 6-13]

Figure 6-13. Head-up Guidance System.

A large fraction of aircraft accidents are due to poor visibility. While conventional flight and navigation instruments generally provide pilots with accurate flight attitude and geographic position information, their use and interpretation requires skill, experience, and constant training. NASA is working with other members of the aerospace community to make flight in low visibility conditions more like flight in visual meteorological conditions (VMC). **Synthetic vision** is the name for systems that create a visual picture similar to what the pilot would see out the window in good weather, essentially allowing a flight crew to see through atmospheric obscurations like haze, clouds, fog, rain, snow, dust, or smoke.

The principle is relatively simple. GPS position information gives an accurate three-dimensional location, onboard databases provide detailed information on terrain, obstructions, runways, and other surface features, and virtual reality software combines the information to generate a visual representation of what would be visible from that particular position in space. The dynamic image can be displayed on a head-down display (HDD) on the instrument panel, or projected onto a HGS in such a way that it exactly matches what the pilot would see in clear weather. Even items that are normally invisible, such as the boundaries of special use airspace or airport traffic patterns, could be incorporated into such a display. While the main elements of such a system already exist, work is continuing to combine them into a reliable, safe, and practical system. Some of the challenges include choosing the most effective graphics and symbology, as well as making the synthetic vision visible enough to be useful, but not so bright that it overwhelms the real view as actual terrain becomes visible. Integrating ADS-B information may make it possible for synthetic vision systems to show other aircraft. [Figure 6-14]

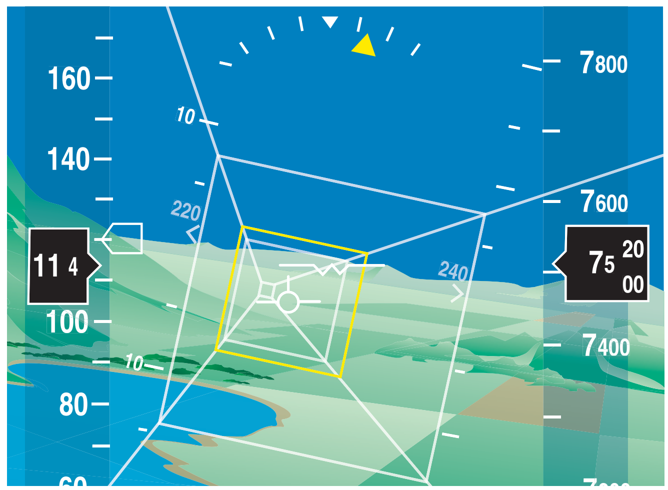

Figure 6-14. Synthetic Vision. This system uses projected images to provide a virtual view of terrain and other data in reduced visibility.

A natural extension of the synthetic vision concept is the **highway in the sky (HITS)** program. This NASA project adds an easy-to-interpret flight path depiction to an electronic flight instrument system (EFIS) type of cockpit display, which may be located on the instrument panel or projected on a HUD. The intended flight path is shown as a series of virtual rectangles that appear to stand like a series of window frames in front of the aircraft. The pilot maneuvers the aircraft so that it flies "through" each rectangle, essentially following a visible path through the sky. When installed as part of a general aviation "glass cockpit," this simple graphic computer display replaces many of the conventional cockpit instruments, including the attitude indicator, horizontal situation indicator, turn coordinator, airspeed indicator, altimeter, vertical speed indicator, and navigation indicators. Engine and aircraft systems information may also be incorporated. [Figure 6-15]

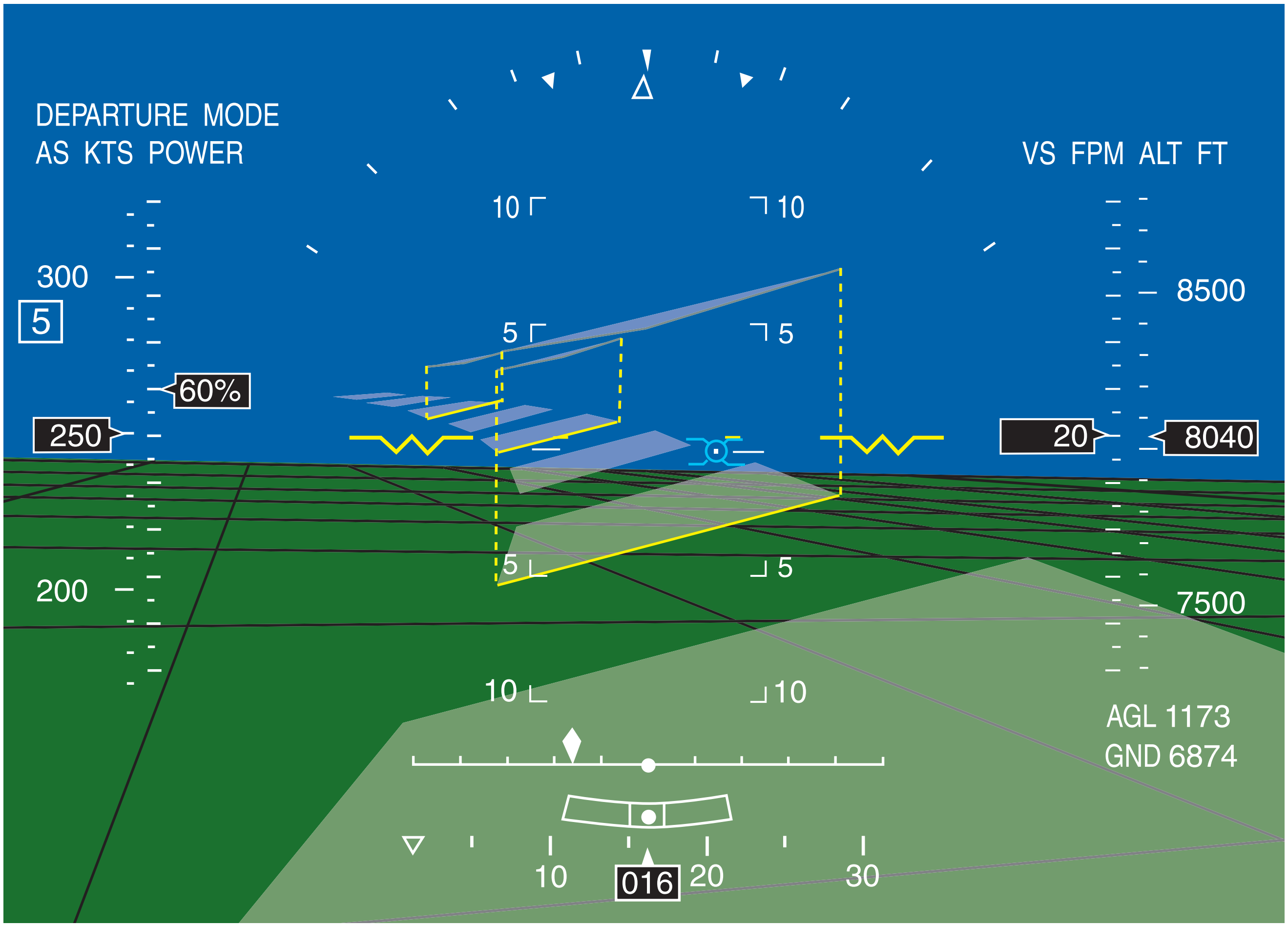

Figure 6-15. Highway in the Sky. The HITS display conveys flight path and attitude information using an intuitive graphic interface.