OPERATING PROCEDURES OF AIRCRAFT AND AIRPORTS LIKELY TO IMPACT THEIR COMPATIBILITY

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Abstract

Some innovative airport capacity improvement concepts that could be safely implemented over the next ten to twenty years are described. Many of these concepts could be quite compatible with today's aircraft and airports in providing air traffic services that satisfy safety and efficiency requirements. To implement many of these near term evolutionary concepts, which have been discussed for many years, very minimal changes are required from existing Air Traffic Control (ATC) operating procedures, as well as improved hardware/software that is either state-of-the-art or nearing the completion of development by the Federal Aviation Administration.

Problem Areas

What are some of the specific areas where aircraft and airport compatibility will be more aggravated unless the FAA engineering and development (E&D) initiatives in airport capacity/delay are exploited to their maximum potential?

First, many air carrier aircraft have flight management computer systems with 4D RNAV capability that can consistently deliver an aircraft over the threshold with an error of 2-3 seconds. However, because of variations in runway occupancy time, aircraft aerodynamic and avionics capabilities, and numerous airport dynamic variables associated with airspace management and airport airfield operational configurations, the present ATC system is capable of providing an 18-21 seconds (1σ) accuracy. This incompatibility, which results in excessive delays and fuel losses will increase as the introduction of new air carrier aircraft (e.g., B-757, 767) are added in significant numbers to the fleet.

Second, the Airline Deregulation Act of 1978 has brought extremely important changes to the U.S. air transportation system. While the full impact of deregulation is yet to be measured, there has been a considerable change in the character of the industry. Patterns of service, route structures, and equipment usage are changing dramatically. At many of the major airports delays have been increasing rapidly, even though only a modest growth in air traffic has been taking place in the past few years.

Third, as more aircraft enter the fleet and become equipped with MLS avionics, operational procedures must be developed to fully exploit the MLS applications that offer potential for improving airport capacity and aircraft delay at congested airports, as well as noise relief to residential communities around the airports.

Fourth, operational solutions to minimize aircraft wake turbulence and the potential for real-time wake vortex prediction and tracking could provide the means to gain back the airport capacity losses that resulted in the early 1970's, when longitudinal separations between leading and trailing aircraft during airport terminal operations were increased up to 6 nmi. and 120 seconds for aircraft arrivals and departures respectively. Unless something is done, this problem will become much worse as more commuter/GA aircraft are mixed in streams containing the larger air carrier fleet.

Finally, airspace and airport demand are expected to increase significantly over the next decade. In order to accommodate that demand it will be necessary to increase capital investment in the system - new and improved airport facilities, navigation and landing aids, and air traffic control facilities. Unless these capital improvements are made there is the potential that in some areas of the country the system will become saturated, and in order to maintain the current high levels of safety, it may be necessary to impose constraints on demand. We all believe that FAA's mission is to develop and maintain a safe and expanding system of airports and airways.

Some proposals are presented later that should allow more compatibility between aircraft and airport issues described previously. First, a discussion of the background of airport capacity, lessons learned from FAA/industry airport capacity/delay studies and analyses, methods to increase airport capacity, major FAA efforts in capacity/delay, and products developed by the FAA should be discussed.

Background

The background of the airport capacity/delay problem is as follows. In the late 1960's the air carriers identified increasing levels of delays in terminal area operations at major air carrier airports. In 1974 the FAA reported to Congress on the eight airports analyzed for airport capacity solutions. This led to the organization of FAA/industry task forces to study the thirty busiest airports in the U.S. Reports have been made public for Chicago O'Hare, Denver, Atlanta, St. Louis, Los Angeles and San Francisco, and the others are expected soon. Using the recommendations from the airport capacity/delay task forces and other promising concepts developed during the most recent E&D initiatives conference, a report was issued in January, 1980 defining those airport capacity initiatives.

IFR delays in the terminal area have been estimated by the task forces to cost users between $500 million and $750 million annually and should approach $5 billion annually in 1999, as shown in Figure 1.

The results of the airport capacity/delay task force studies are summarized in Figure 2. Using the airport airfield capacity and delay simulation models, the FAA applied these tools to estimate both the present average delay estimates (eight minutes per average aircraft operation) and the 1987 delay (25 minutes per operation). It was found that both near term and far term airfield and E&D improvements were needed to cope with future demand at major airports.

As shown in Figure 3, based on the use of these models, peak hour IFR demand exceeds IFR capacity today at large hub airports by about 143 percent. The airport analyses indicate delays now reach one hour and more per aircraft operation during IFR peaks, and that delays averaged eight minutes per aircraft operation at those hubs in 1978 and have increased steadily through 1980.

To summarize the situation regarding delays, three main conclusions can be drawn.

(1) Even if only a modest two percent annual growth in aircraft operations is considered, the task forces believe that delays may average 25 minutes per aircraft by the year 1987. This means that even with moderate growth the problem is becoming increasingly more severe.

Figure 1. Cost delays (IFR) in terminal area.

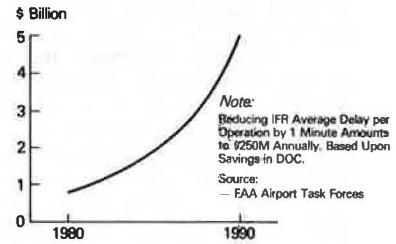


Figure 2. Task force results.

- Developed and Applied an FAA Airport Airfield Capacity Model and Delay Simulation Model, Which Received Broad Acceptance by Aviation Community.
- Average Delay per Operation at Five Airports (ATL, DEN, JFK, LGA, SFO) Runs 8 Minutes (1978) and Increasing to 25 Minutes in 1987.
- Demonstrated to the Aviation Community, Based on Believable Delay Cost Basis, that Both Near Term (1982-1985) & Far Term (1987-1990) Airfield and E&D Improvements'Are Needed to Cope with Demand at Major Airports.

Figure 3. Task force results using airfield capacity delay models.

IFR Demand - Capacity

Airport	Peak Hour IFR Operations: Demand	Peak Hour IFR Operations: Capacity	Demand/ Capacity
ATL	137	107	(128%)
DEN	99	63	(157%)
JFK	88	53	(166%)
LGA	77	60	(128%)
SFO	72	53	(136%)
Average			(140%)

Source: Task Forces (ATL, DEN, NY, SFO)

(2) Considering the airport facility improvements contemplated by the task forces at the airports mentioned, they found that new runways which allow independent IFR operations would afford the biggest benefits by reducing average delays approximately 50 percent.

(3) Near term improvements such as ATC procedures and more navigation aids can provide modest gains, except at JFK where average delay reductions of about 30 percent may be possible. However, even if all the non-technology (operational) improvements were implemented - and many are controversial at the airports and even within the task forces - delays can be expected to be 50 percent greater by the mid-80's than they are today.

The causes of airspace and airport system delay are illustrated in Figure 4 and can be summarized as follows:

- the proximity of other airports,
- ATC rules, regulations and procedures such as separation standards, runway occupancy rules, and the impact of wake vortex on spacing requirements,
- physical limitations on airspace/airfield,
- meteorological conditions,
- available minimums,
- runway configuration management, and
- airport demand.

The question that must be addressed next is what are the fundamental ways to increase airport

Figure 4. Causes of airspace/airport system delays.

Although 84% of NASCOM Delays Are "Weather Related", the Following Factors Are Also of Importance to System Delays:

- The Proximity of Other Airports
  - (e.g., JFK, LGA, EWR)
- Air Traffic Control Rules, Regulations, and Procedures
  - Arrival Separations (3, 4, 5, 4, 6 rule)
  - Runway Occupancy (Only one aircraft allowed on runway)
  - Departure/Arrival Spacing (Currently limits departure if following arrival less than 2 nm from threshold)
  - Departure Separation
    Wake Vortex Effects IFR & VFR Alike
    HH: 90 Sec.; HL, HS: 120 Sec.; All Others: 60 Sec.
- Physical Properties of the Airspace/Airfield
  - E.g., Obstructions, Displaced Thresholds, Exit Locations and Intersections, Gate Locations Relative to Exits; Weight Restrictions on Runways
- Meteorological Conditions
  - For a Constant Demand Average Delay at ORD Can Vary Between 3 and 37 Min./Operation Because of Prevailing Wind Conditions, Capacity Changes Dramatically with Changes in Ceiling/Visibility; Braking Action Increases ROT
- Available Minimums
  - Unavailability of Precision Approach Guidance Increases Delays During Reduced Weather Minimal Conditions
- Runway Configuration Management
  (Selection of maximum capacity configurations based upon weather, equipment, demand, etc.)
- Aircraft Demand
  (En route & terminal area; arrival/departure, queues; gate availability)

Because of the factors cited above, the efficiency of the system requires an optimal balance between all of the above. What are some of the fundamental ways to increase airport capacity and hence reduce aircraft delays?

capacity and reduce airport delays. Basically, airport capacity can be increased by:

- improvements to airports,
- reducing the IFR separation standards,
- creating additional IFR arrival streams, and
- managing the demand for aircraft services during peak hour operations.

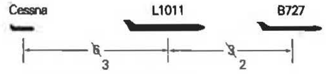
First, increasing the efficiency at airports by the addition of new runways, taxiways, NAVAIDS, and ATC procedures could reduce the delays as much as 50 percent. However, it is unlikely that full implementation can take place at the congested airports.

Second, as shown in Figure 5, reducing aircraft IFR separation standards to 2-3 miles could save between 50-75 percent in aircraft delay costs. It is unlikely that full implementation would occur throughout the system without lengthy and extensive operational testing. The major hurdle in the reduction of IFR longitudinal separation standards is the alleviation and avoidance of wake turbulence hazards to following aircraft.

One of the most promising ways to increase airport capacity is to provide more arrival streams to conduct instrument approaches. This is illustrated in Figure 6. Such approaches, either independent or dependent, would be made to existing runways that are presently available at many of the congested hub airports. These concepts include converging (non-parallel) approaches and the combination of parallel and converging approaches that are used today during VMC conditions. We have identified a total of 89 airports which could provide for 134 potential applications of one or more airport capacity improvement concepts. Benefits in improved arrival capacity when compared with a single runway range from 40-50 percent for dependent approaches, 100 percent for independent approaches, and a 140-155 percent capacity improvement for triple approaches.

Finally, demand management can help. Today there are quotas at O'Hare, Kennedy, LaGuardia, and Washington National, and if demand management and

Figure 5. Reduced IFR separations.



- Could Save 50-75% of Delays
- Full Implementation Unlikely
- Wake Turbulence Problems

Figure 6. More IFR separations.

- Non Parallel, Reduced Parallels, Small Aircraft Streams, Triples
- Could Save Up to 50% of Delays
- Requires New Research
  - Present Separation Standards Limit Application to VMC Only
  - New Operational Procedures Need to be Developed to Exploit Full Potential

Figure 7. MLS **applications.**

- Provides Independent Streams of Commuter/GA Aircraft to Separate Short Runways
- Provides Simultaneous Approaches to Triple Parallel Runways
- Provides IFR Capability of Non-Parallel Approaches
- Reduction in the 4300 Foot Independent Parallel IFR Centerline Separation Requirement
- Accomodate Dependent IFR Approaches to Closely Spaced Dual Lane Runways Under Wake Vortex Constraints
- Simplified Siting Criteria for Small Airports

redistribution were applied throughout the national air system, a 50 percent reduction in delays could be achieved. Techniques such as holding aircraft on the ground and flow control are additional methods to manage the demand, and today these procedures are mandatory during the emergency period presently in force. The issue is still debatable as to whether demand and delay management will be voluntary or mandatory after the ATC system is rebuilt.

The benefits of microwave landing systems (MLS) are of major concern today, and they show great promise for increasing airport capacity as shown in Figure 7. MLS can provide the means to safely guide instrument approaching aircraft and accommodate missed approaches to separate short runways, triple parallel runways, converging runways, and during instrument operations, to independent parallels with less than 4300 feet centerline spacing. Higher glide slope requirements for ILS operations to closely spaced runways could assist wake vortex operational solutions by keeping lighter aircraft above and away from the hazardous wake vorticies. Finally, small airports can be accommodated more readily with MLS.

Use of separate, short runways for general aviation and commuters provide an operational solution to vortex separation problems and help cope with the growth of general aviation/commuter operations. But such runways must be located in positions where they can be operated completely independently. Full use of such runways at specific airports may require the definition of triple parallel operations, as at O'Hare, Dallas/Ft. Worth or Atlanta. Resolution of airspace conflicts may be required as for example at Kennedy where the small runway exists but is not routinely used because of potential conflicts with other operations. The precision paths available from MLS should help. MLS may provide solutions to potential obstacle clearance, terrain or siting problems at Denver, where a study was recently completed on the feasibility of a short general aviation runway.

MLS may help reduce the 4300 foot parallel separation requirement for general aviation and commuter traffic on parallel short runways by providing additional navigation precision, high glide path angles for extra spacing, and as above, by providing precision missed approach capability, MLS would also provide the ability to restructure approach paths at selected airports to permit segregated approaches to short runways by general aviation, helicopters, and commuter operators. The use of the variable glide paths available with the MLS will permit small aircraft to follow "heavies" at a higher glide path angle as a means to ensure protection from wake turbulence.

Next, the current major Engineering and Development programs of the FAA are reviewed.

Wake Vortex

When the wake vortex problem was recognized nearly ten years ago, two efforts were undertaken. One, by NASA, concentrated on the mechanics and causes of wake vorticies, and methods to alleviate them at the source. These efforts have not reached the stage where either the airframe manufacturers or the users feel implementable wake vortex alleviation systems are achievable.

FAA undertook the development of wake vortex detection and avoidance systems, and has been moderately successful in characterizing wakes and developing meteorological ways to predict the probable location of wake vorticies. A system under test at O'Hare has proven technically workable, but has not been found operationally acceptable by some of the users.

It is clear that the current promise of full wake vortex detection and alleviation system is less than NASA or FAA had hoped. While the research and development work will continue, and there is some hope for active wake vortex sensors, we must concentrate also on other approaches, because the wake vortex problem continues to be a major constraint to IFR capacity. This year we are planning to test the performance of NOAA's FM-CW Doppler weather radar to detect wake related echoes from large aircraft landing at Denver.

Automated Metering and Spacing

Automated metering and spacing has long been discussed as a potential source of at least evening out capacity at a given airport, and some have felt that capacity might be increased. Yet, the achievement of automated metering and spacing in implementable form has proven elusive. We have come to appreciate the truly remarkable capability of human controllers to manage terminal air traffic and to achieve efficient airport operations -- capacities which may be extremely difficult to duplicate with automation. There are, of course, things that have been done and there are more things that will be done, especially as the problem of fuel conservation becomes more critical.

Operational Techniques for Capacity/Delay Improvement

Washington has been working with the Great Lakes Region to design a configuration management system for O'Hare to aid the assistant chief (AC) of the facility in the selection of best runway configuration to minimize delays. A basic system was tested

Figure 8. Longer term E&D programs.

- Continuation of Wake Vortex R&D
  - Vortex Alleviation
  - Prediction and Tracking of Vortices
  - Knowledge of Vortices Beyond Outer Marker
- Automated En Route ATC (AERA) System
  - Major Automation Process
  - Will Feed Integrated Flow Management Program
- IFM-Optimize Fuel Efficiency of ATC System While Maximizing Airport Thruput
- Cockpit Display of Traffic Information (CDTI)
  - Possible Aid to Pilot Acceptance of Automation and Reduced Spacing

Figure 9. FAA flow programs in operating services.

- Central Flow Control Facility
  - Fuel Advisory Departure Procedures (FAD)
    - Voluntary Cooperation with the NAS
  - Quota Flow
    - Management of High Altitude Air Traffic
- En Route (ARTCC's)
  - En Route Metering Implementation in Progress at 20 NAS Stage A Centers that Service 18 Terminals (ERM-1)
- "Operation Free Flight"
  - Study Reviewed the System of Today and Found that a Limited Capability Exists to Handle Direct Flights.
- National Airspace Review
  - A Systematic Review of the Current Airspace Operations & Efficiency:
    (1) Evaluation of Airspace Structure at FL 180 and Above
    (2) Evaluation of Airspace Structure Below FL 180, and
    (3) Integration of E&D Programs, Systems & Procedures into NAS.

off-line at O'Hare. It incorporates equipment/runway outages, wind and ceiling visibility, demand and Midway Airport interactions. We are developing an enhanced runway configuration management system that will be capable of operating in a "stand alone" computer system for the AC in keeping airport capacity at peak levels.

Also, the phase of evaluating the technical feasibility of instrument approaches to separate short runways for commuters/general aviation, to converging runways, to close spaced parallels for independent and dependent operations, to triple runways and operational solutions to wake vorticies for closely spaced parallels has been completed.

Integrated Flow Management

A "strawman" concept and operational description has been developed for a program called integrated flow management. This program should help achieve optimal trade-offs between delay, capacity and fuel efficiency at major terminal complexes in the longer term. The integrated flow management concept must integrate the functions of national flow management, en route metering, terminal flow and airport operations. This concept will use automation tools to permit the best possible integration of a variety of services and capabilities, including optimal fuel-efficient flight paths, the capabilities of 3D and 4D area navigation, adequate wake vortex protection, an optimum metering, sequencing and spacing system to ensure minimum time deviation over the threshold, the capability to provide conflict-free paths which recognize limitations of weather and shear, and runway

Figure 10. Bottom lines.

- Reduced Longitudinal Spacing from 3.0 to 2.5 nm (IFR) Possible Today Under "No-Wake-Vortex-Hazards" Conditions
  Requires:
  - Removal of Wake Vortex Restrictions when Wakes Are Not a Factor
  - Development of Operational Procedures
  - Acceptance by Pilots/Controllers
- Further Reduction to 2.0 nm Minimum
  Requires:
  - Solution to the Vortex Problem
  - Improved Runway Occupancy Times
  - Better Over-the-Threshold Delivery Accuracy
  - Resolution of Operational Problems
  - Development of Operational Procedures
  - Acceptance by Pilots/Controllers
- Solution to Improved Traffic Flow Not Based Solely on Maximizing the Landing Rate of a Runway; a Balance of Aircraft Demand, Terminal Area Operations, and Airport Capacity is Required to Achieve Optimal Airport Thruput.
- Upgraded O'Hare Runway Configuration Management System Being Developed for Test and Evaluation at ORD (9/81).
- Integrated Flow Management
  - Critical Element in Optimal Tradeoffs Among:
    - ☐ Delays
    - ☐ Capacity
    - ☐ Fuel Consumption
  - Must Integrate the Functions of:
    - ☐ National Flow Management
    - ☐ En Route Flow
    - ☐ Terminal Flow
    - ☐ Airport Operations
    - ☐ New Aircraft Capabilities — 3D/4D RNAV, Performance Computers

occupancy time monitoring and control. A method for best integrating these capabilities into the system and establishing the impact of ATC automation planning will be examined.

Figure 8 summarizes several programs under way for the longer term. FAA and NASA both are continuing to work on improvements in wake vortex alleviation and avoidance, and another search for a long-range, real-time vortex sensor which can reach out beyond the outer marker will be made. The work being done in the automated en route air traffic control system, the AERA program, will evolve into terminal automation as well, and will become an element of the integrated flow management (IFM) system. The IFM program will achieve optimum fuel efficiency while maximizing aircraft flow through the airport. The FAA program to examine the capabilities and limitations of cockpit displays of traffic may show that they can be a part of the future terminal system.

The operating services of the FAA have accomplished several things related to improvements in aircraft flow as illustrated in Figure 9. For example:

- Central flow control has been operating successfully for a number of years and is improving. It has provided an important operational element which can be fed into an integrated flow management system. Fuel advisory procedures have been implemented to absorb severe delays on the ground with significant fuel savings.

- Terminal area delays are minimized by providing to the centers realistic acceptance rates at an airport for the runway configuration in operation, and a more efficient flow of aircraft results in the system.

- Implementation of the first phase of en route metering is nearing completion for 18 of the busiest airports. Today's system can accommodate some direct flights

Figure 11. A rough estimate of potential savings from improvements at specific airports.

Applications of	At These Airports	Potential Total Annual Savings of
■ Triple Parallels	ORD	$10 M[1]
■ Reduction of Parallel Runway Spacing Reqts.	DEN	$10 M[1]
■ IFR Approaches to Converging Runways	DEN, DFW, IAH, MIA, ORD, STL, New York	$70 M[1]
■ Separate, Short GA Runway	ORD, ATL, PHL, DFW, JFK, DEN, STL	$60-150 M[2]
■ Configuration Management	ORD	$15 M[1]

Note: These benefits are an estimate of potential savings only and are not cumulative; require E&D products (e.g., MLS, etc.)

Sources: [1]Task Forces; [2]FAA-EM-79-19

Figure 12. Airport capacity/delay E&D products.

	Development Completed
■ Reduced Final Approach Spacing Feasibility Analysis to Achieve 3.0, 2.5 & 2.0 nmi Minimum Longitudinal Spacing	8/79
■ Potential Benefits of Using Short Runways at 30 Major Aiports	9/79
■ Feasibility Study of a Separate Short Runway for Commuter and GA Aircraft at Denver	9/80
■ Development of a Terminal Area Airspace Model for Application on Integrated Flow Management Program	9/80
■ Completed Validation of Airfield Delay Simulation Model for FAA/Industry Airport Task Forces	9/80
■ Methodology for Analyzing Feasibility of Dependent Parallel Instrument Approaches for	
– Analysis of Airborne Separation	9/80
– Control of Mixed Arrival & Departure Runway Operations	9/80
■ Completed Development of Upgraded FAA Airfield Capacity Model	3/81
■ Safety Analysis & Equipment Requirements for Independent & Dependent Parallel Instrument Approaches at Reduced Runway Centerline Spacing	5/81
	Due Date
■ Safety Analysis, Equipment & Controller Staffing Requirements & Preliminary Procedures for	
– Instrument Approaches to Triple Parallel Runways	9/81
– Instrument Approaches to Converging Runways	9/81
■ Safety Analysis, Equipment & Procedures Required for Reducing Aircraft Longitudinal Spacing to 3 nmi on Instrument Approaches to Dependent Parallel Runways	9/81
■ Real-time Planning Aid for O'Hare Assistant Chiefs to Consistently Select Maximum Aircraft Thruput for ORD	
– Initiate Test & Evaluation of Runway Configuration Management System	9/81
– Complete Test & Evaluation, Document Software	9/82

for air carriers with flight management computer systems. A more comprehensive review of the national airspace has been initiated by the FAA and this activity is expected to continue actively into 1984.

Benefits

What are the results, benefits, or "bottom lines" as they are commonly called, from these developmental activities? They are summarized in Figure 10. Briefly,

- Minimum longitudinal separation standards for IFR can be reduced from 3.0 to 2.5 nmi, when wakes are judged not to be a factor. Operational testing and evaluation of procedures are required before implementation can be initiated.

- To achieve a 2 nmi. minimum spacing requires a solution to the wake turbulence problem, as well as compatibility between runway occupancy times and over-the-threshold delivery accuracy. However, testing and evaluation of operational changes is still required.

- A balance between demand, terminal area operations and airport capacity is the key to optimal airport thruput.

- A configuration management system for assistant chiefs at O'Hare has been developed and is ready for test and evaluation.

- The IFM program is a critical element in trade-offs between aircraft delays, airport capacity and fuel consumption. All of the functions of national, en route and terminal flow as well as airport and aircraft capabilities must be integrated in a systematic manner.

Figure 13. Summary of aircraft flow improvement programs.

- ■ Wake Vortex Relief and Reduced Longitudinal Spacing
- ■ O'Hare Runway Configuration Management
- ■ Use of Separate Short Runways by GA and Commuter
- ■ IFR Approaches
  - – Triple Parallels
  - – Closely-spaced Parallels
  - – Converging IFR Approaches
- ■ Reduction of Parallel Runway Spacing Requirements
- ■ Airport Surface Traffic Control
- ■ Microwave Landing System Applications
- ■ Integrated Flow Management (Including metering and spacing)
- ■ Automated En Route ATC System Development and Extension
- ■ Cockpit Display of Traffic Information
- ■ Demand Management Impact Assessment

Several potential improvements which promise high payoff as seen by the task forces and the FAA are discussed next. These improvements have the potential to reduce the cost of delays by millions of dollars as shown in Figure 11, but fall short of completely eliminating them, particularly if increased aircraft operations and changes in mix impose greater demand on airports in the future. Federal expenditures for R&D to accomplish them appear worthwhile, but they may be viewed only as ameliorations of the problem. Complete solutions are likely to be achieved only through major capacity increases that involve the construction of new runways. In some cases, new airports, and more intensive management of demand, including the redistribution of traffic between airports may be required to make the most efficient use of available capacity.

Figure 12 presents a list of FAA engineering and development products showing the studies, analyses, models, methodology, safety analysis and equipment/controller staffing requirements developed for the highly promising airport capacity improvement concepts. The major product that is ready for testing and evaluation is a real-time planning aid for the O'Hare assistant chiefs to consistently select the maximum capacity configuration for that airport.

Finally, Figure 13 summarizes the aircraft flow improvement programs. Perhaps the most interesting and the most valuable airport capacity/delay improvements in the long run are direct and indirect techniques to overcome the wake vortex problems, better innovative use of runways and runway configuration, the use of separate short runways at major airports by general aviation and commuters, independent and dependent IFR approaches including reduction in IFR centerline spacing requirements for independent approaches, applications of the microwave landing systems, and an integrated flow management concept. The prospective payoff from technology changes and improvements seems high, and seems to us to be very much worthwhile. The technology can offer important benefits, but probably not enough to solve the anticipated problems of capacity, demand, and delay, even under modest growth assumptions. However, in the near term, significant terminal area capacity improvements would result in the system if the operating procedures that have been developed for all the innovative concepts are tested and accepted by the users and operators of the ATC system.