FAA-74-26

REPORT NO. FAA-RD-75-51

AIRPORT SURFACE TRAFFIC CONTROL SYSTEMS DEVELOPMENT ANALYSIS-EXPANDED

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MARCH 1975
FINAL REPORT

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PREPARED FOR
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington DC 20591

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-75-51		

4. Title and Subtitle
AIRPORT SURFACE TRAFFIC CONTROL SYSTEMS DEVELOPMENT ANALYSIS - EXPANDED

5. Report Date
March 1975

6. Performing Organization Code

7. Author(s)
R.A. Bales and J.F. Koetsch

8. Performing Organization Report No.
DOT-TSC-FAA-74-26

9. Performing Organization Name and Address
The Mitre Corporation*
1820 Dolly Madison Blvd.
McLean VA 22101

10. Work Unit No. (TRAIS)
FA421-R5512

11. Contract or Grant No.
RA-73-11

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Aviation Administration
Systems Research and Development Service
Washington DC 20591

13. Type of Report and Period Covered
Final Report
January 1973-February 1974

14. Sponsoring Agency Code

15. Supplementary Notes
*Under contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. Abstract

A previous MITRE Technical Report, Airport Surface Traffic Control Systems Deployment Analysis, FAA-RD-74-6, presented an analysis of ASTC (Airport Surface Traffic Control) system requirements and developed estimates of the deployment potential of proposed ASTC system alternatives for 19 air carrier airports. The primary requirement was determined to be improved surveillance which resulted in an estimated deployment of one of two surveillance systems at 16 airports by 1980. This report presents an expansion of that deployment analysis to include a total of 39 air carrier airports. The methods and assumptions for the deployment analysis of the 20 airports presented in this report are essentially the same as in the initial report. The overall result of the analysis is that by the initial deployment date (1976-1980) of the two alternative surveillance systems, the total potential market will be for 20-25 systems. By the end of the century, the total potential market for ASTC surveillance systems will exceed 30.

17. Key Words
Deployment Analysis, Airport Surface Traffic Control, Airport Surface Detection Equipment

18. Distribution Statement
DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	120	

PREFACE

The work described in this report was performed as a part of the Airport Surface Traffic Control (ASTC) Program at the Transportation Systems Center. This program is sponsored by the Department of Transportation through the Federal Aviation Administration (FAA), Systems Research and Development Service.

The work consists of a cost/benefit analysis of two different controller aids at each of twenty (20) airports. The aids are ASDE-3, a new ground surveillance radar, and ASE, an advanced ARTS-like system for the cab. The results are a list of dates for which the operations level at each airport would be high enough to warrant each controller aid on a cost/benefit basis. The results are intended solely as a guide to the R&D work of the ASTC program. They do not represent an actual system deployment plan or schedule. Such a plan is the responsibility of the FAA Operating Services and must consider all aspects of such a deployment. Such items as method of procurement, system compatability between ASE and ASDE-3, and movement costs associated with replacement of an ASDE-3 by an ASE if they are not compatible should be and are being considered.

Since the cost/benefit analysis in this report was performed, some errors in system costs and benefits have come to light. Ideally the analysis could be redone to incorporate the new data, but time and costs make this impractical and fortunately the effors are of such a nature as to offset each other leaving the overall results essentially unchanged. Specifically, the costs of the aids as used in this report do not adequately reflect the FAA costs of installing and commissioning equipment and, hence, are low. However, it has been pointed out that the savings in passenger delay (@ $10 per passenger hour of delay) should be added to the reductions in airline operating cost of delay (@ $10 per air carrier minute of delay) used as the sole benefit measure in this report. With an average air carrier load of 60 passengers (based upon recent studies of O'Hare air carrier traffic) the passenger delay is converted to $10 per air carrier minute of delay which increases the benefits and offsets the increased system costs.

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1. INTRODUCTION

Reference 1 presents an analysis of the potential deployment of candidate ASTC (Airport Surface Traffic Control) systems at 19 commercial airports. This paper is an expansion of that analysis covering 20 additional airports. The methods and assumptions are essentially the same as those established in Reference 1. Expanding the deployment analysis from 19 to 39 airports will include the top 45 air carrier airports in the U.S., excluding six good weather airports. The purpose in expanding the analysis was to estimate the total potential marked for the two major candidate ASTC systems: ASE (Advanced Surveillance Equipment) and ASDE-3 (an improved Airport Surface Detection Equipment). It was decided that by expanding the deployment analysis by 20 additional airports, the potential market would be safely exhausted. It is unlikely that commercial airports with less demand than the 39 airports included would require an ASDE or ASE by the time either system becomes available. The results from Reference 1 and the analysis of the 20 airports presented here will be summarized together to present a deployment schedule that should exhaust the potential market for each of the two candidate systems. The motivation for the initiation of the ASTC studies, summarized here and in Reference 1, was as follows:

1. Tower control workload overloads due to increasing air traffic demand and restricted runway/taxiway/ramp facilities under normal operating conditions (good visibility weather). This includes the potential deterioration of the level of service provided to surface traffic as control workloads reach critical levels as well as the increased difficulty of controlling surface traffic due to visibility obstructions resulting from expansion of terminal buildings in the direction of the taxiways and, in some cases, runways.

2. The tower control workload overloads which restrict the capability to handle traffic safely under reduced visibility weather conditions. The prime motivation in this area is to match the tower control system capability with present and planned improvements in the operational capability of landing systems.

The tower control problem areas were initially investigated by a survey of 19 airports. The data included: visual observations, interviews with tower personnel, collection of data of record and an analysis of tower communication tape recordings at selected airports. Data were also collected from regional FAA authorities and airport authorities on facility expansion and improvement plans aimed at meeting the projected air traffic demand.

A preliminary requirements analysis (Reference 2) was performed from the above survey for three baseline airports to: quantify the control tower problems, establish the degree of relief achievable with alternate conceptual ASTC systems, and to establish physical limits on airports' operational capacity. The conclusions were essentially that:

1. Significant performance improvements could be achieved by deployment of ASDE (Airport Surface Detection Equipment) with an improved (bright) display under bad visibility conditions. However, the performance would fall short of that achievable under good visibility conditions without any additional controller aids. Consequently, ASDE should be considered to be only an interim improvement at airports where a large number of aircraft can be expected to land in Cat II and III weather conditions. The major improvement needed in bad visibility operations is a reduction of workload involved in surface traffic control and the creation of a control environment independent of visibility conditions. This would require a superposition of a data block (identity, aircraft type and possibly destination on the airport surface) on a planar display covering the tower control area (outer marker to airport surface and airport surface).

2. Major performance improvements, independent of tower visibility, can be attained by the introduction of ASE (Advanced Surveillance Equipment) providing the controllers with a planar display of traffic (to outer marker) including alphanumeric data on aircraft identity/status and a system for calling controller attention to aircraft requiring control services.

3. Additional, less pronounced, improvements of performance capability can be achieved, if needed, by the introduction of STR (Standard Taxiway Routing) patterns and AICS (Autonomous Intersection Control Systems) to further reduce routine and conflict workloads, respectively, and to provide for smoother traffic flow patterns.

Reference 1 extended the three-airport analysis to a total of 19 airports and established a tentative deployment schedule of system alternatives. The deployment schedule was established on the basis of a capacity/demand ratio criterion, derived in the paper, aimed at limiting the delays encountered by aircraft when the required systems are available. Otherwise the peak hour demand growth was assumed to be limited until the required system became available and normal growth was resumed following the removal of the capacity limiter.

The data collected in the expanded survey for the analysis in this paper were not as extensive as the survey of the initial 19 airports. Pertinent data for the analysis covering airport operations, present capacities and future airport expansions were obtained by a mail and telephone survey without a visit to the airports. As a result, airport layout maps will not be presented in this report. Also, no attempt will be made to repeat the detailed description of the candidate ASTC Systems nor the development of controller performance measures as described in Reference 1. This report will review the deployment analysis approach and then will present the application of that approach for each airport.

2. ANALYSIS APPROACH

This section presents the controller performance measures that were developed in Reference 1, the deployment criteria to be used in the subsequent airport-by-airport analysis in Section 3 and a summary of the general system costs. The only difference in methodology from the Reference 1 analysis is the assumption on the good visibility demand limitations. It was assumed in Reference 1 that demand growth, including all GA (general aviation) and AC (air carrier) traffic, was limited to the level of performance of the LC (local controller)/runway system in good visibility operations. This assumption seemed reasonable for most of the airports treated in Reference 1 because they were mostly air carrier hubs and thus the bad visibility (CAT II and IIIA) traffic demand was not too much different from the good visibility demand. It also seems reasonable, as happened at the air carrier hubs, that as an airport grows in air carrier operations the VFR-only traffic will be forced to use other smaller airports and the percent of air carrier type aircraft will increase. Therefore, in this analysis, the demand will be permitted to grow until the air carrier demand plus the instrumented general aviation demand reaches the runway capacity.

2.1 PERFORMANCE MEASURES

The tower controller performance values, P, used in this study for the LC (local controller) and GC (ground controller) are presented in Table 2-1 and 2-2 respectively. The development of these values is presented in Reference 1. A more complete description of the candidate systems is also presented in References 1 and 3; however, a brief description of each system in the two tables is as follows:

1. ASDE - Airport Surface Detection Equipment. An analog ground surveillance radar with a PPI (Plan Position Indicator) display. The one in use presently is the ASDE-2, and the improved one being developed will be the ASDE-3.

2. ASE - Advanced Surveillance Equipment. An improved surveillance system that will provide both the local and ground controller with a planar display covering the tower control area (out to the outer marker for the local controller). The display will include an ARTS III type data block indicating aircraft location, identity, whether the aircraft is an arrival or departure, alerts to the controller when a pilot requires attention, etc.

TABLE 2-1
LOCAL CONTROLLER OPERATIONAL PERFORMANCE VALUES (OPH)

RUNWAY CONFIGURATION	GOOD VISIBILITY	BAD VISIBILITY WITH NO ASDE	BAD VISIBILITY WITH ASDE	BAD OR GOOD VISIBILITY WITH ASE
Single Runway, Mixed Operations (S)	54	40	43	60
Independent Arrival and Departure Runways (IP)	93	65	72	103
Dual Lane[(1)] (D) (D')	81 86	58 58	65 65	60 96
Near End Crossing (N)	93	65	72	103
Far End Crossing (F)	65	50	54	72
Crossing in Middle	76	56	62	85

(1) Values for D are for runway pairs which are so spaced than no more than one airplane can be held between them.
Values for D would allow for two or more airplanes to be held between them.

TABLE 2-2

ESTIMATED PERFORMANCE VALUES (OPH)
FOR GROUND CONTROLLER VERSUS
PROGRESSIVE SYSTEM IMPROVEMENTS

SYSTEM	GOOD VISIBILITY		BAD VISIBILITY	
	1GC	2GC	1GC	2GC
UNIMPROVED TAXIWAY SYSTEM(1)				
NO ASDE	81	130	35	--
ASDE			46	64
IMPROVED TAXIWAY SYSTEM(2)				
NO ASDE	90	138	35	--
ASDE			48	68
ASE	115	175	115	175
STRS AND AICS	162	≫200	162	≫200

(1) Unimproved taxiway system is the current set of taxiways at a subject airport in which some deficiencies which prevent exclusive one-way traffic flow normally exist.
(2) Improved taxiway system is a modification to the current set of taxiways at a subject airport correcting the deficiencies to permit exclusive one-way traffic flow.

3. AIC - Autonomous Intersection Controller. A traffic control device designed for individual taxiway intersections using loop sensors for detection and light bars for control lights.

4. STR - Standard Taxiway Routing. A system that would provide the pilot with a taxiway route other than from the ground controller. It is considered as a candidate system only in that if a data link is established the function could be automated. The service can be partially accomplished now by the clearance delivery controller for departures or by use of the ATIS (Automatic Terminal Information Service).

The two different entries in Table 2-2 for the ground controller for the Improved and Unimproved Taxiway System represents the two estimates for ground controller performance for airports on which one-way traffic flow patterns can be established versus airport configurations in which deficiencies exist that prevent a one-way traffic flow.

2.2 DEPLOYMENT CRITERIA

The deployment criteria are developed separately for good and bad visibility conditions, inasmuch as the bad visibility conditions occur during busy hours only about 10-40 hours per year, while problems associated with good visibility are a daily occurance. The generalized criteria developed in the following paragraphs are not dependent on the control position (ground and local).

2.2.1 Good Visibility Deployment Threshold

The deployment threshold for any of the alternative ASTC systems is taken as the point at which estimated yearly aircraft delay costs exceed the yearly cost of the system. The delays are estimated under the assumption that a controller cannot provide the required services to aircraft at a higher rate than some value P. If the demand exceeds this capacity, P, then a queue is created and aircraft are delayed until an under demand period occurs that is sufficient to service all of the aircraft at the rate P.

The delay equation for good visibility operations can be written in terms of demand and capacity rates as;

$$D = 30t^2 \left[\frac{(N_1-P)(N_1-N_2)}{P-N_2}\right], \text{ where} \qquad (2\text{-}1)$$

t = Duration of the oversaturation period in hours

N_1 = Demand rate during oversaturation period in operations per hour

N_2 = Demand rate during the following period, when the waiting lines are absorbed, in operations per hour

P = Capacity of the system in operations per hour

D = Total aircraft delays in minutes

The derivation of equation (2-1) assumes that aircraft operations are generated at a uniform rate, N_1 per hour, during time t and that during the following under-demand period aircraft operations are generated at a uniform rate, N_2 per hour. However, it is well known that demand is not generated at uniform rates. Aircraft delays occur due to departure queues even when the hourly demand is much lower than the capacity. Reference 3 shows that, within a peak hour, demand is generated in spikes (primarily departures), generally on the hour, half-hour, quarter-hour, etc. Therefore, for this study, it has been assumed that during some portion of the hour, t, the demand peaks and during the remainder of the hour a trough exists at a lower demand level. This was necessary because demand data for projecting future demand did not exist other than by the hour. The particular value of t was chosen to be 20 minutes and the ratio of the peak 20 minutes to the 40 minute trough was 1.3 to 1.0. These values appear to be reasonable from examining the demand profiles of peak hours in Reference 4. At airports that are not yet approaching capacity, it appears that the peaking factor would be much greater than 1.3.

Since the deployment criteria is defined for airports operating at or near capacity, when the demand in many of the busy hours are at or approaching the peak hour demand, it was assumed a necessary requirement that aircraft delays be absorbed within the hour in good visibility conditions, to prevent excessive buidups of delays. Now using the peaking relationships discussed above:

$t = 1/3$ hour,

$N_1 = 1.3N_2$,

$\frac{N_1 + 2N_2}{3} = d$, the average hourly demand,

$N_2 = \frac{d}{1.1}$,

$N_1 = \frac{1.3d}{1.1}$,

and equation (2-1) can be written in terms of P and d as follows:

$$D = \frac{d}{1.1} \left[\frac{1.3 - 1.1 \ (P/d)}{1.1 \ (P/d) - 1} \right] , \qquad (2\text{-}2)$$

$= d \ K$, where

K = average delay per aircraft

The delay coefficient (K) is plotted in Figure 2-1 as a function of the ratio between capacity and average demand, P/d. It should be noted from Figure 2-1 that the average delay per aircraft will be held within reasonable bounds if P/d is held above one and will begin rising rapidly if P/d falls below that value. This is obviously undesirable from the viewpoint of generating large delays. Moreover, operations below a P/d ratio of one will result in an overflow into the succeeding hour, or hours, and will generate progressively larger delays. On the basis of the examination of Figure 2-1 it appears that a good operating level, capable of absorbing capacity and demand perturbations, would be at about a P/d ratio of 1.1.

The above criterion checks fairly closely with ARO (Airport Reservation Office) ceilings, Reference 5, established at JFK, ORD, DCA and LGA as summarized in the tabulation below:

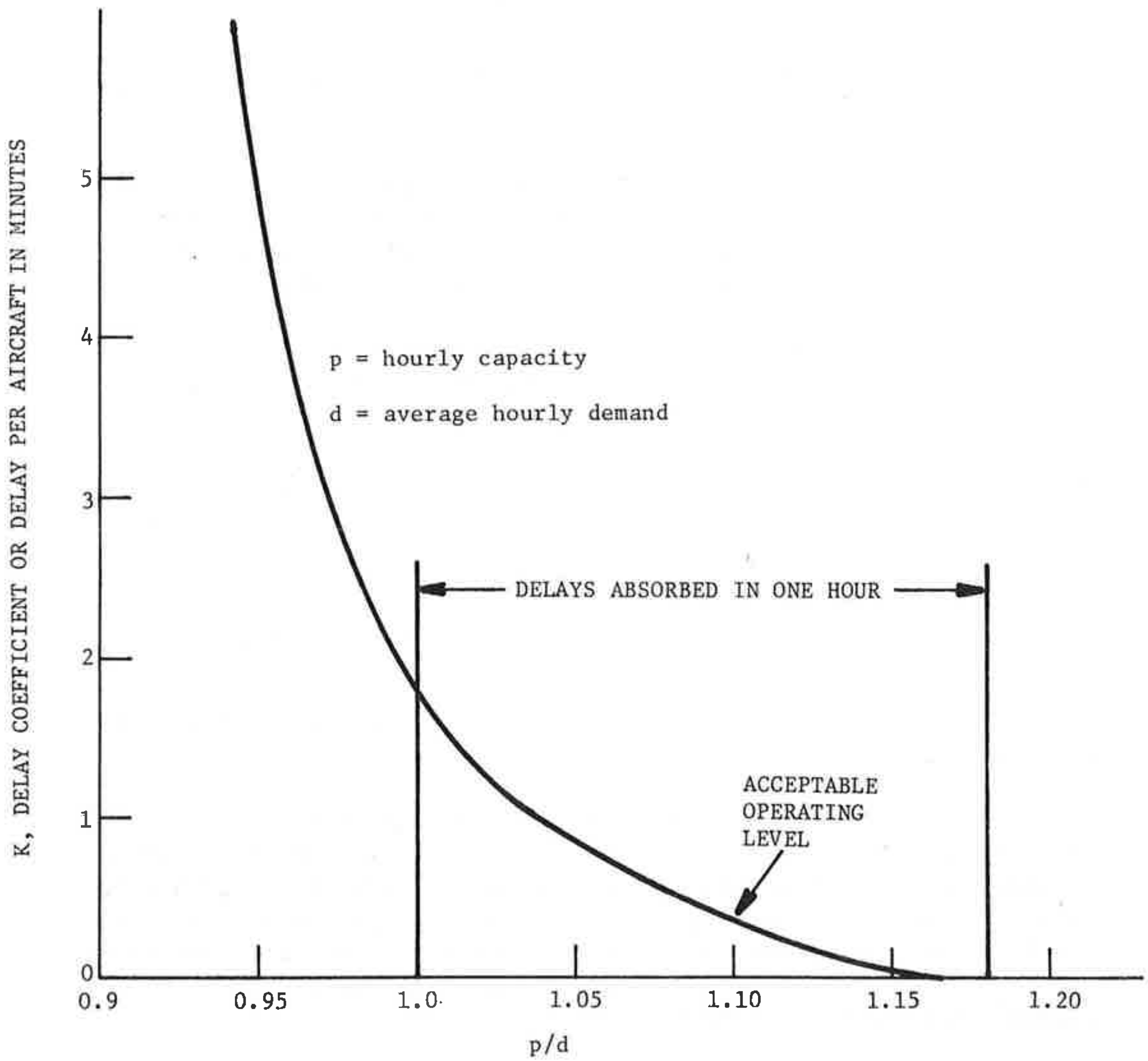

Figure 2-1. Aircraft Delay Versus Hourly Capacity To Demand Ratio

Airport	Ceiling	Estimated Capacity	P/d
JFK	80	86	1.07
ORD	135	158	1.17
LGA	60	93	1.55
DCA	60	81	1.35

The ratio's at JFK and ORD agree very closely with the 1.1 criteria.

Since the bulk of the traffic during peak hours at JFK and ORD are air carriers and the peak hours at LGA and DCA contain a larger percentage of general aviation, it appears that a P/d of 1.1 reflects the scheduling of air carrier operations.

Given the assumption of a capacity/demand ratio of 1.1 the average delay per aircraft delayed during a saturated hour (i.e. P/d = 1.1) would be nominally 0.4 minutes.

Considering that these delays occur 250 days out of 365 per year (i.e. on a daily basis), this would result in an approximate yearly cost of delay (C_D) of:

$$C_D = K\ d\ n\ C_m(250) = 0.4(250)\ d\ n\ C_m = 100\ d\ n\ C_m$$

where n is the number of peak hours per day and C_m is the aircraft operation cost per minute.

Equating the above to the yearly cost of a system (C_s) yields a deployment threshold for the given system in terms of delays due to saturation. Therefore, in addition to operational benefits such as a decrease in congestion, departure queues and arrival stacks, the deployment of the given system, which will increase capacity by at least 5% (that is reduce K to zero), is also financially justified when:

$$nd = \frac{nP}{1.1} \geq \frac{C_s}{100\ C_m} \qquad (2\text{-}3)$$

For example, assuming that the yearly cost of the most expensive system to be considered is $600,000 and that the delay cost per aircraft per minute is $10 (Reference 6) the deployment threshold is 600. Consequently, at an airport with a saturation rate of 60 operations per hour the deployment of the system would be justified financially if the saturation persisted for 10 hrs per day.

To summarize, the above deployment criterion will be used to determine whether an airport qualifies for a given system under the assumption that peak hour demand will be held to about 10% below capacity until a sufficient number of peak hours is generated, by demand redistribution over the day, to justify a deployment of an improved system. The growth of non-peak hours, after the demand peak reaches 10% below capacity, will be assumed to be linear between the year that one or more hours first reach saturation and the year that all of the busy hours reach the saturation level.

Busy hours, as used herein, occur usually between 0700 and 2200, and include the peak hours. See Appendix C for specifics.

The demand data for this analysis were obtained from References 7 and 8. Reference 7 presents for a typical busy day the hourly demand profile for air carrier operations for each airport. This profile was then adjusted to include the general aviation operations by assuming that the same relationship be applied to the hourly counts as the relationship between the yearly number of total operations versus air carrier operations. This latter relationship was taken from Reference 8 which presents present and projected yearly operations for air carrier and general aviation operations. The unconstrained demand lines presented in Section 3 for good visibility conditions for each airport are based on a linear projection of the demand profiles discussed above using the 1973 and 1983 yearly operations to determine the growth rate. The unconstrained demand lines for bad visibility conditions were generated in the same manner except that only 20% of the general aviation operations were included. In 1971 at ORD, LAX, ATL, JFK, and SFO the percent of general aviation itinerant arrivals that were instrument approaches were 15%, 20%, 15%, 10%, and 10% respectively (Reference 9). It is reasonable to expect that when improved landing systems are available, these percentages should increase. Therefore, for this analysis, the percent of general aviation that will also operate in bad visibility conditions was nominally taken as the highest of the 1971 values considered, i.e., 20% of the general aviation good visibility operations.

The unconstrained demand lines described above were used in the analysis except where the combined good visibility capacity of the local controller/runway system constrained the peak hour growth in bad visibility conditions, i.e., when the largest bad visibility peak hour demand reaches P/1.1, the peak hour demands in good or bad visibility conditions is constrained at that level. As stated earlier, this was done because the "VFR-only" aircraft are generally not treated the same and they will most likely move to smaller airports as the airport grows into an air carrier hub. However, the total bad visibility demand was assumed to continue to grow at the same rate as the unconstrained demand growth until all of the busy hours for that airport reach the saturation level. It did not seem reasonable to allow bad visibility capacities to limit demand since it occurs infrequently; also, since the capacities described previously for the ground controller are not hard limits, it did not seem reasonable to allow ground controller capabilities to limit demand growth.

In order to project the number of non-peak hours in good visibility conditions that grow to saturation level, to satisfy equation (2-3), it was necessary to project the growth of the busy hour demand profile after the first peak hour reaches the saturation level. Assuming that an airport has a nominal number of busy hours, Z, (from Reference 7 it was found that about 90% of the daily traffic occurs in the busy hours) then the number of peak hours will reach a maximum of Z when 90% of the yearly demand reaches 365Z P/1.1, or

$$.9(a_2 + a_1 T_s) = \frac{365Z\ P}{1.1} , \qquad (2\text{-}4)$$

where

a_1 = yearly growth rate in operations from Reference 8,

a_2 = yearly operations in the year, Y_1, in which the first peak hour reaches saturation,

Z = number of busy hours for the airport,

T_s = number of years from Y_1 until all Z hours are saturated,

P = performance capacity in operations per hour, OPH, of the local controller in good visibility.

Therefore, the number of years from Y_1, when the first peak hour reaches saturation, when all of the busy hours will be saturated, can be estimated by solving equation (2-4) for T_s, or

$$T_s = \frac{365Z\ P - .99a_2}{.99a_1} . \qquad (2\text{-}5)$$

Now, assuming that the number of busy hours that reach saturation, n, grow linearly, n can be defined as

$$n = n_o + \frac{(Z-n_o)}{T_s} T_1 \qquad (2\text{-}6)$$

where

n_o = the number, usually one, of peak hours that initially reach the saturation level

T_1 = time in years after Y_1 to reach n peak hours.

The determination of Z is made by inspection of the daily demand per hour profile of Reference 7. The determination is usually very obvious, typically over the hours from 0700 to 2300. The actual values for the airports studied ranged from 14 to 19 hours.

The methods presented thus far are based on the present capacity of the ASTC system and assumes that the alternative system being considered will eliminate all of the delays. Because of the logical deployment sequence of alternative systems in good visibility, i.e., ASE before any others, the assumption is valid. Also it must be pointed out that the methods were developed for local controller operations. Since, as explained before, the ground controller capacity limits are not hard limits, the threshold for deployment has been based on a one-to-one ratio between peak hour capacity and demand instead of the 1.1 ratio developed for the local controller. Otherwise, the methods are the same for the local controller and the ground controller.

2.2.2 Bad Visibility Deployment Threshold

The methods presented in the previous subsection for good visibility conditions are based on the fact that peak hour saturations occur daily. Bad visiblity conditions during busy hours are infrequent occurences and accumulate much fewer yearly delays than daily good visiblity saturation. The methods presented for justifying the cost of alternate ASTC systems in bad visibility conditions are based on the constrained demand levels determined by local controller capabilities in good visibility conditions. The basic equation, which was developed analogously to the good visibility model, for estimating delay costs of a bad visibility system is:

$$C_D = 30\ (\$10)t^2\ f\ \frac{x}{Z}\ (N_1-P_1)\ \frac{(N_1-P_1+P_2-N_2)}{(P_2-N_2)}\ , \qquad (2\text{-}7)$$

where

Z = number of busy hours for that airport,

f = yearly frequency of bad visiblity (CAT II and IIIA) periods each of which exceed a predetermined time,

t = average duration in hours of those bad visibility (CAT II and IIIA) periods which exceed a predetermined period of time,

P_1 = value of P for the bad visibility system,

P_2 = value of P for the good visibility system,

x = number of busy hours in which the demand exceeds P_1,

N_1 = average demand of the x hours, and

N_2 = average good visibility demand following the bad visibility period.

The model is based on the assumption that f times a year a bad visibility period will occur of duration t hours during which delays/queues will be created because the demand N_1 is greater than the capacity P_1 and the queues will be extinguished in the good visibility demand N_2 is less than the good visibility capacity P_2. The x/Z term is used as a measure of the probability that the bad visibility period will overlap a bad visibility peak demand period. It is expected that when the delays begin accelerating because of growing demand, equation (3-7) will give a conservative estimate of the delays.

The values of f and t were estimated from Reference 9, 10 and 11 and are based on CAT II and IIIA visibility conditions. Values for x, Z, N_1 and N_2 were derived from References 7 and 8; the basic data being the per hour demand profile for a typical busy day for air carrier and general aviation traffic projected as described in subsection 2.2.1. The daily profile is then rank ordered and a straight line is drawn between the peak hour OPH, h_1, and the least demand hour OPH, h_2, of the Z busy hours.

This approximation appeared to fit the rank ordered profiles very well. The number of hours in which the bad visibility demand exceeded the bad visibility capacity P_1 could then be defined as

$$x = \frac{(h_1-P_1)Z}{(h_1-h_2)} \quad . \qquad (2\text{-}8)$$

Values for the demand, N_1 and N_2, were estimated assuming that the bad visibility demand, N_1, was the average of the peak hours that exceed P_1, or, $(h_1+P_1)/2$, and the good visibility demand, N_2, was the average of the good visibility hourly demands, or, $(h_1+h_2)/2$.

The rationale, then, for deciding for a given year, whether or not an alternative ASTC system could be justified was to compute the yearly delay costs for the existing system and the alternative system using equation (2-7) and comparing the difference in those delay costs to the yearly cost of the alternative system.

2.3 SYSTEM COSTS

The estimated cost of the alternative ASTC systems are presented in Table 2-3. The costs are based on cost estimates from References 12 and 13. The installation costs in the table were assumed to be 60% (Reference 14) of the hardware investment cost, which would include installation, certification, etc.

The AIC and STR systems were not included in Table 2-3 because, as will be shown in Reference 1 and in Section 3, neither system had a potential for deployment at any of the airports. The reason is that neither of the systems affect the local controller/runway operations, and all of the airports become runway limited at a demand level that is lower than the ground controller capacity. Since the ASE improves the capacity of both the local controller and ground controller, it was the only alternative for good visibility operations, and with an ASE, the ground controller capacity is well above the demand levels constrained by the runway capacity.

The System/Module entries in Table 2-3 are based on maximum interchangeability of modules between systems. The radar for the analog radar system is the same as for the digitized radar system, and the display and computer in the digitized radar system are the same as in the trilateration system. As shown in Figure 2-2 upgrading from one system to another may require less cost than buying a new system because of unit interchangeability. In upgrading from an ASDE to a digitized radar system, the cost of the radar and its installation is not incurred again so the incremental cost is only $295,000. Since the analog bright displays with the ASDE cannot be used with the digitized radar system, they can be relocated to another

TABLE 2-3

SYSTEM COST ESTIMATES

SYSTEM/MODULE	COST (1000)
ANALOG RADAR SYSTEM (NEW ASDE)	
Radar	$ 180
Installation	100
Display (5 Bright)	45
Installation	30
Total Cost	$ 355
DIGITIZED RADAR SYSTEM	
Radar	180
Installation	100
Displays (5)	45
Installation	25
Digitizer	60
Installation	35
Computer	80
Installation	50
Total Cost	$ 575
TRILATERATION SYSTEM	
Two Interrogators	90
Installation	55
Three Receivers (Minimum)	65
Installation	40
Displays (5)	45
Installation	25
Computer	80
Installation	50
Total Cost	$ 450

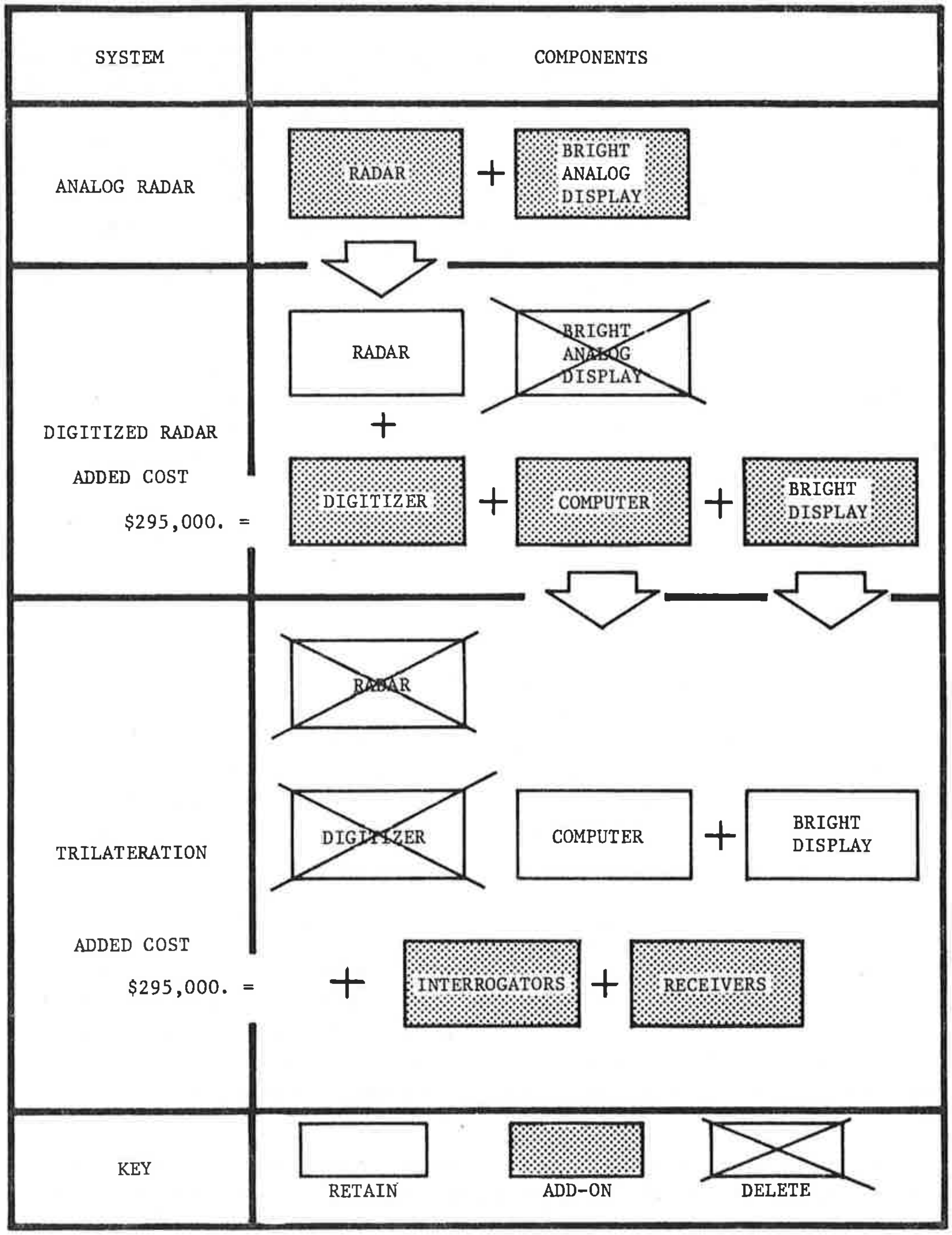

Figure 2-2. Modular System Evolution

airport that has a requirement for an ASDE or additional displays. Upgrading from a digitized radar to a trilateration system would require only the addition of interrogators and receivers ($35,000 per receiver) since the computer and displays should be interchangeable. The minimum incremental cost would be $250,000 for an airport requiring only 2 interrogators and 3 receivers and as high as $675,000 for an airport requiring 2 interrogators and 15 receivers. As before, the radar and the digitizer could be relocated to another airport with part of the upgrading cost recoverable by this means.

The cost of the analog radar system is based on a new ASDE. The $45,000 for ASDE display includes 5 bright displays. Airports with less than two local controllers and two ground controllers will not require as many. The cost of slave displays are $4,000 each.

As stated before, the radar in the digitized radar system is the same as the ASDE but the display is different. The cost of the total system is based on one radar.

The minimum trilateration system cost is based on three receivers, and two interrogators. The number of receivers required at a particular airport will depend on the geography of the individual airport in order to insure complete coverage. The estimate of how many were required at a particular airport was made by inspection of the airport map with the general criteria that sets of three receivers should not have obstructions between them.

Although an orderly implementation of ASTC systems is desired with maximum interchangeability, since the exact order of implementation and condition of the equipment in the system to be replaced cannot be assured, it was decided to use the total system costs in the analysis. This may overestimate the system costs which would yield a conservative estimate of the potential deployment year in that the system may be justified earlier.

To be compatible with the delay models presented earlier, the system costs in Table 2-3 have been converted to yearly costs. This was accomplished by amortizing the system costs over a ten year period, which is the expected useful life of the equipment, and adding an estimate of the yearly operating and maintenance costs.

Also, since it is expected that at least one additional controller will be required for either ASE system, $75,000 per year was added to those yearly costs. An interest rate of 6% was used to yield a yearly amortized cost of 13.6% of the combined investment and installation costs. The yearly operating and maintenance costs are expected to be 15% of the investment costs (Reference 13). Therefore, the yearly costs of the ASDE is $82,000, the digitized radar is $208,000 and the trilateration system ranges from $185,000 to $240,000. At a particular airport the yearly cost of the ASE system was taken as the average between the digitized radar and trilateration system.

2.4 DEPLOYMENT ANALYSIS PROCEDURE

The approach taken for the deployment analysis of each airport is identical, and they were all based on the capacities, models and costs presented in the previous subsections. The general approach is presented here and a complete example is presented in Appendix C. The steps of the analysis were as follows:

1. Plot the projected unconstrained demand bad visibility peak hour versus the present good visibility capacity of the local controller/runways. Determine when the demand grows to within 10% of the capacity. If runway expansion plans exist for the airport, assume that they would be instituted at that time to accommodate the demand. After all expansions have been included, again determine when the demand grows to within 10% of the capacity. Calculate from equations (2-3) and (2-6) when the ASE will be justified. Since the ASE will not be available until 1980, if this date occurs before 1980, the peak hour demand growth is constrained until 1980 when it is again permitted to grow due to the installation of ASE until it reaches 10% less than the ASE capacity level.

   If the date is 1980 or beyond, the ASE is deployed and the peak hour demand is permitted to grow until it reaches 10% below the ASE capacity level. This constrained demand after runway improvements and installation of the ASE is plotted for the other three cases: ground controller in good visibility and bad visibility, and local controller in bad visibility. The deployment analysis is conducted independently for each of the other three combinations. No deployment dates beyond the ASE, local controller in good visibility deployment are considered because that combination is the limiter on demand.

2. The present capacity of the ground controller in good visibility is compared to the constrained demand to determine if the ASE could have been justified earlier than the local controller in good visibility/ASE deployment date.

3. Determine if an ASDE can be justified at present for either the local controller or ground controller in bad visibility conditions or in a year previous to the ASE deployment date from the good visibility cases above.

4. If an ASDE is justified, determine if an ASE can also be justified for either controller before the good visibility deployment dates for ASE. In comparing delay costs with an ASDE versus an ASE, it is assumed that even if there is only one ground controller for good visibility conditions, a second ground controller can be added when an ASDE is in use for the brief period of the bad visibility condition.

The determination in steps (3) and (4) of the year for deployment is accomplished by interpolation between the differences in system delay costs for two selected years. The selected years are generally 1973 and the ASE deployment date in good visibility. The interpolation of system differences in delay costs were assumed to be linear between the two years, which appeared reasonable since both points occur before the demand becomes constrained, hence the delays would not yet have begun to accelerate rapidly.

3. AIRPORT SYSTEM DEPLOYMENT SCHEDULES

This section presents the estimated deployment schedules for each of the 20 airports surveyed (ordered in the following subsections by yearly air carrier operations) using the methodology presented in Section 2. For each airport the following will be presented:

1. A discussion of the airport runway and taxiway configuration including the operational scenario of the preferred runway configuration. This discussion will represent a summary of the information collected in the mail/telephone survey.

2. A table summarizing the inputs to the deployment analysis. The table will be presented in two parts: the first part contains estimates of weather conditions and the second part contains estimates of airport system capacities. These inputs are defined as follows:

   a. Weather Conditions - The data presented were estimated from data in References 10 and 11. Estimates were made of the frequency and average duration of bad visibility conditions (CAT II and IIIA) that persisted for more than 90 minutes during busy hours.

   b. Demand - The present yearly demand values and future projected yearly demand values were taken from Reference 8. The 1973 peak scheduled air carrier operations per hour were taken from Reference 7. The total peak hour demand values are based on the assumption that bad visibility demand will grow until it is constrained by the good weather runway capacity, i.e., the demand values used in the analysis includes the air carrier demand plus 20% of the general aviation traffic (that portion of the general aviation traffic that was estimated earlier to be instrumented for bad visibility operations).

   c. Capacities - The runway configurations used were those selected by the control tower personnel to be the preferred configuration during air carrier peak hours. The resulting capacity values were taken from Table 2-1 in Section 2, and are based on air carrier operations. Since this report assumes that "VFR-only" traffic will gradually move to smaller airports as the airport becomes an air carrier hub, runways for "VFR-only" general aviation traffic are not included in the runway capacity estimates. The data on gates, from the survey, are presented although gates are not used as a constraint on demand in the analysis. The capacities are based on an average of 45 minutes service time in the gate and an average gate utilization factor of 60%.

3. The information described above will be used in the following subsections to construct a graphical representation for each airport showing years when demand saturates capacity in good and bad visibility conditions for each control position and what ASTC system should be implemented to alleviate the saturation. A complete example of the analysis computations for the Dallas-Fort Worth Airport is presented in Appendix C.

3.1 DALLAS-FORT WORTH AIRPORT (DFW)

The following summarizes the results of the ASTC deployment analysis at DFW. At the time of this writing the air carrier traffic and facilities are moving from Dallas Love Field (DAL) to DFW. Therefore, the present demand data are from DAL operations.

3.1.1 Present Facilities and Operations

The present runway configuration at DFW (scheduled to open 13 January 1974) consists of: two north-south 11,400 foot parallel air carrier runways, 17/35 L and R, 6500 feet apart; and one 9,000 foot crosswind air carrier runway, 13/31, which does not cross the nearby parallel runway 17L/35R. The terminal area is between the two parallel runways. The preferred configuration for air carrier traffic will most likely be to use the two parallel runways independently for arrivals and departures each or to use R17R/35L (Runway 17 left/35 right) for arrivals and departures, and to use R17L/35R and the crosswind runway in combination: one for arrivals and the other for departures. This latter configuration will yeild a higher capacity since all three runways are utilized and should be the preferred combination when peak hour demand dictates.

The taxiway system appears to be adequate with parallel taxiways between each of the parallel runways and the terminal area. A potential problem may exist for traffic crossing from one side of the terminal area to the other if cross taxiways are not completed.

The initial gate complex will consist of 68 gates, 61 of which can be used by jumbo jets. This gate configuration should easily handle present demand.

3.1.2 Future Facilities and Operations

The future expansion of DFW is quite extensive. The airport may grow eventually to nine runways: the two present north-south runways extended to 20,000 feet to handle jumbo cargo operations, another 13,400 foot parallel to the present 13L/31R, another set of parallels 1200 feet outboard of the two present north-south parallels designated 18/36 L and R, and three general aviation runways. The priority for expanding the air carrier runways appears to be to (1) extend the existing runways, (2) put in the new parallels 18/36 L and R and then (3) put in runway 13R/31L.

The gate complex is expected to be expanded to about 90 gates by 1980, of which 80 could accommodate jumbo jets, and to 120 gates by the 1990 time frame, of which 100 could accommodate jumbo jets. These expansions should easily accommodate the projected demands in those time frames.

3.1.3 Deployment Time Phasing

The inputs to the deployment analysis for DFW are presented in Table 3-1 and the ASTC systems deployment time phasing is summarized in Figure 3-1. An ASDE can be justified at present for the ground controller in bad visibility. However, an ASE cannot be justified, based on communications workload, until 1995. The ASE can then be justified for the ground controller in bad visibility or good visibility. An ASE may be justified earlier at DFW if the distances from the control tower to the extremeties of the airport layout create a surveillance problem. If two ground controllers are not used when the airport opens, a second one should be added by 1980. Again, because of the distances involved and since a two-sided operation is used, the second ground controller may be required sooner. The tower at Dallas Love Field (DAL) presently uses two ground controllers.

3.2 STAPLETON INTERNATIONAL AIRPORT, DENVER, COLORADO (DEN)

The following summarizes the results of the ASTC deployment analysis at DEN.

TABLE 3-1
DEPLOYMENT ANALYSIS INPUTS: DFW

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
1.9	2.2	0700-2300	67	293 419	422 555	73	102

System Capacities

PERIOD	REPRESENTATIVE (1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(17R),S'(17L,13L)	147 163	105 115 163	90 175	35 68 175	68	109
FUTURE	D(17R,18R), S'(17L,13L)	174 193	123 137 193	138 175	35 68 175	90	144

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

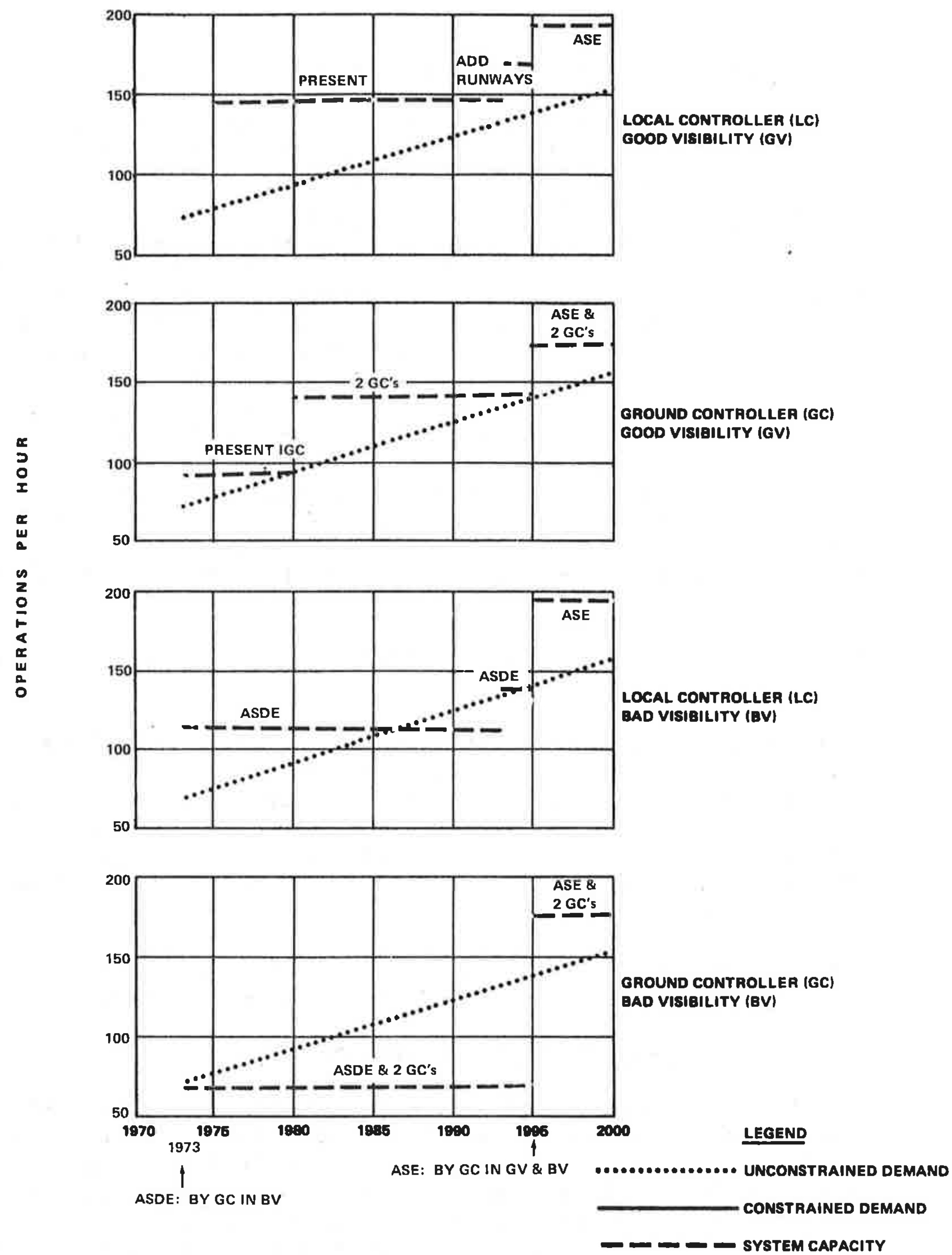

Figure 3-1. Dallas-Fort Worth International ASTC Systems Deployment

3.2.1 Present Facilities and Operations

The present airport runway layout at DEN consists of three runways: a set of dual lanes (8/26L and R) 1000 feet apart (8L is 7924 feet long and 8R is 10,010 feet long) and a crosswind runway perpendicular to the 8/26 pair, R17/35 (runway 17/35) which is 11,500 feet long. Runway 17/35 does not cross either of the dual lanes; it is located to the north of the dual lane pair, the near end of R35 being about 2200 feet from the middle of R8L/26R. The terminal area is located between the near end of R35 and R8L/26R toward the 8L end of R8L/26R. All three runways are air carrier runways, but only R8R/26L can accept heavy jets. R8L/26R can accept only the lighter jets, up to B-727. Due to noise restrictions, the preferred runway configuration is arrivals on R26L and R and departures on R35. This configuration is used about 85% of the time. Operations west or south of the airport are avoided when possible for noise abatement reasons. However, when required because of wind conditions, single runway operations are performed on R35 (10% of the time).

The tower cab uses two local controllers (one for arrivals, one for departures) and one ground controller.

When the preferred runway configuration is being used, there appears to be no major problems with the taxiway system. However, if arrivals use R8L or R, the most convenient taxiway to the terminal is unusable for air carrier jets; and when a single runway operation is used on R17/35 in either direction, arrivals and departures frequently are forced to use the same taxiway or area on the apron.

There are presently 70 air carrier gates at DEN, which should satisfy the peak hour demand for about the next 10 years.

3.2.2 Future Facilities and Operations

The only major improvement in the foreseeable future for DEN is a new runway, now under construction, R17L/35R. The runway will be 12,000 feet long and it will be located 1600 feet east of the present R17/35. The 35 end of the new runway will be displaced to about the center of R17R/35L. It is due to be available in 1975-76. The new runway will not improve the peak hour capacity of the preferred runway configuration. It will increase the capacity of the crosswind configuration to almost match the preferred configuration capacity.

The only gate improvements appear to be in upgrading the present gates to handle jumbo jets.

3.2.3 Deployment Time Phasing

The inputs to the deployment analysis for DEN are presented in Table 3-2 and the ASTC systems deployment time phasing is summarized in Figure 3-2. An ASDE will be justified for the ground controller in bad visibility by 1979. The local controller performance will also benefit from the ASDE at that time. The ASE will be required by 1982 to increase the local controller in good visibility capacity to meet the peak hour demand. The ASE would also decrease the delays created in bad visibility by both controllers and it should permit a single ground controller to handle the traffic in good visibility.

3.3 LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT (STL)

The following summarizes the results of the ASTC deployment analysis at STL.

3.3.1 Present Facilities and Operations

The present runway configuration at STL consists of four runways: a set of dual lane runways, 12R/30L (10,000 feet long) and 12L/30R (6600 feet long), located to the north of the terminal area 1500 feet apart, of which R12R/30L is primarily an air carrier runway and the other is a general aviation runway; another air carrier runway, 6/24 (7600 feet long), that crosses R12R/30L about 2500 feet from the 12R end and crosses R12L/30R at the 12L end; and a general aviation runway, 17/35 (6000 feet long), that crosses the dual lane runways at about 2200 feet and 3000 feet respectively from the 30L and 30R ends. The air carrier terminal area is located to the southwest of R12R/30L and between the 6 and 35 ends of R6/24 and R17/35. The preferred runway configuration for air carrier operations during air carrier peak periods is R12R for arrivals and departures. Runway 6/24 could be used in addition to form a near end crossing configuration.

There are two local controllers on duty during peak good visibility periods.

The taxiway system is adequate to establish a one-way traffic flow except on one taxiway near the end of R30L. A small fixed-base operator is located there, but since the traffic is so infrequent, it does not create a major problem.

TABLE 3-2
DEPLOYMENT ANALYSIS INPUTS: DEN

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
1.3	2.1	0700-2400	57	183 344	292 468	67	102

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV PRESENT ASE	BV NO ASDE ASDE ASE	GV PRESENT ASE	BV NO ASDE ASDE ASE		
1973	Arrive - R26L&R, Depart R35	108 120	65 72 120	90 115	35 68 115	70	112
FUTURE	Same as Above						

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

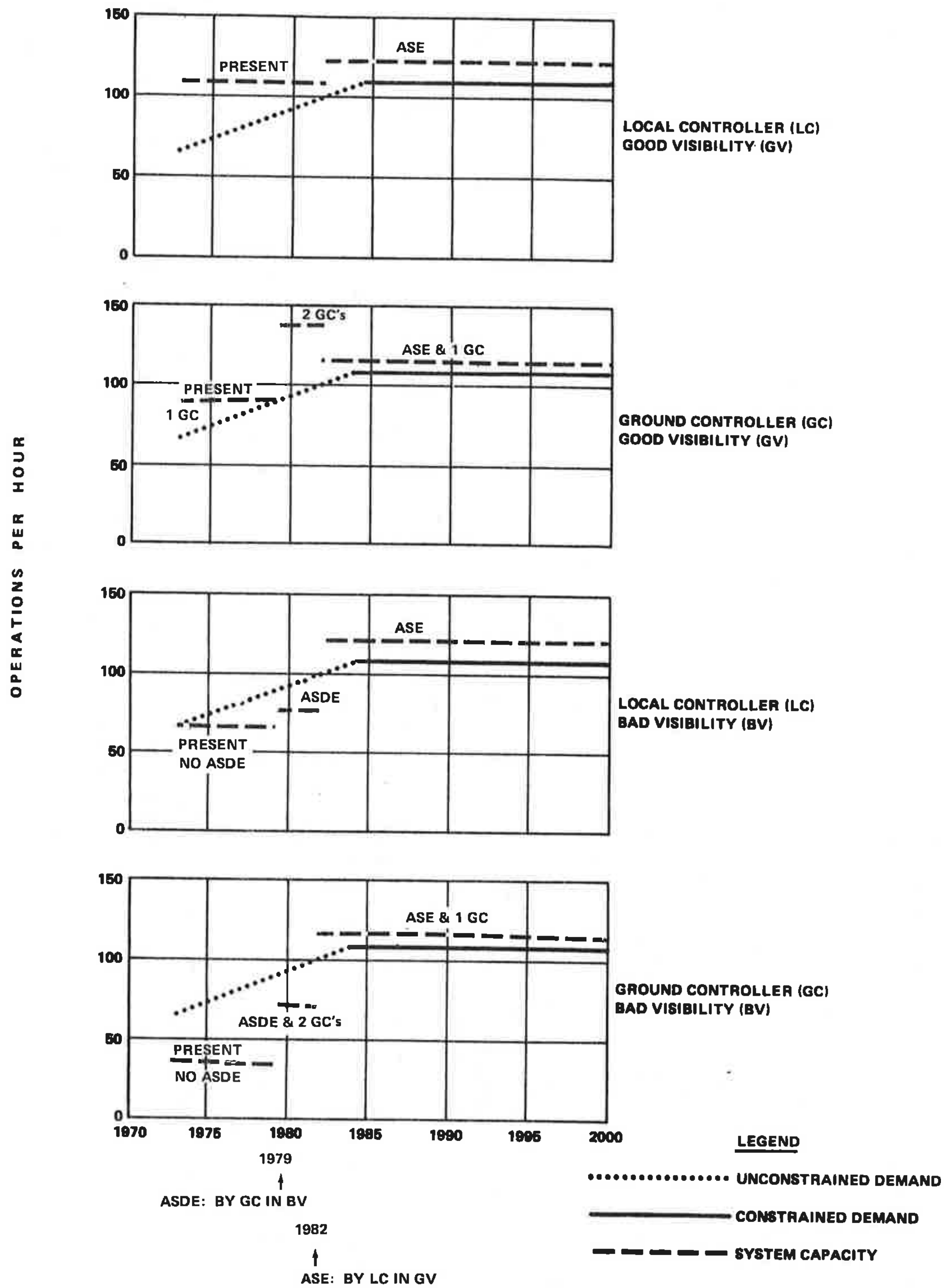

Figure 3-2. Stapleton International Airport
ASTC Systems Deployment

TABLE 3-3
DEPLOYMENT ANALYSIS INPUTS: STL

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
3.0	3.07	0700-2300	48	166 318	236 386	57	77

System Capacities

PERIOD	REPRESENTATIVE (1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(12R)	54 60	40 43 60	90 115	35 68 115	35	56
FUTURE	D(12L,R)	81 90	58 65 90	90 115	35 68 115	-	-

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

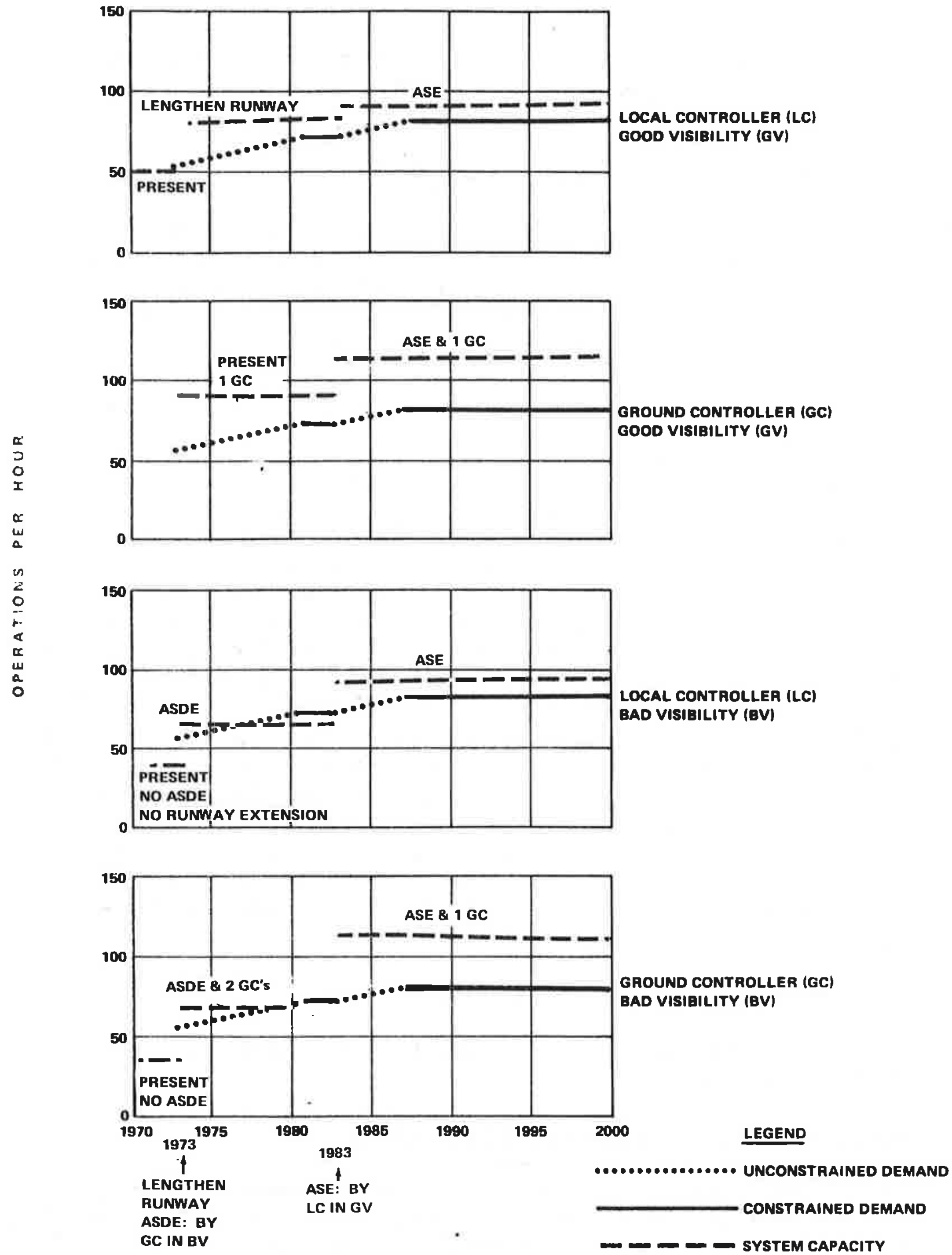

Figure 3-3. Lambert-St. Louis International Airport ASTC Systems Deployment

The present gate complex consists of 35 air carrier gates, of which 2 can accommodate jumbo jets. The resulting gate capacity is barely adequate to satisfy the present peak hour traffic.

3.3.2 Future Facilities and Operations

A master plan for airport expansions has not been completed. It is unlikely that new runways could be constructed due to the lack of space. However, it appears that R12L will be extended to permit a dual lane operation for air carriers. Also, R12R will most likely be extended to 13,000 feet to handle jumbo jet transports.

3.3.3 Deployment Time Phasing

The inputs to the deployment analysis for STL are presented in Table 3-3 and the ASTC systems deployment time phasing is summarized in Figure 3-3. An ASDE can be justified at present for the ground controller in bad visibility. The ASDE would also increase the local controller's bad visibility capacity to a level above the present demand. It also appears necessary at present to increase the local controllers good visibility capacity. The extension of the other dual lane runway should be instituted or the crossing runway should be used in conjunction with the present air carrier dual lane runway. In either case, the peak hour demand will approach the local controller/runway capacity in about 1981 and by 1983 there will be a sufficient number of peak hours approaching the capacity to justify an ASE. In this case, the total demand was permitted to grow from 1981 until 1983 when a second busy hour reached the level to justify the ASE. One peak hour at that capacity level could not generate enough delays to justify the system.

3.4 Houston Intercontinental Airport (IAH)

The following summarizes the results of the ASTC deployment analysis at IAH.

3.4.1 Present Facilities and Operations

The present runway configuration at IAH consists of two air carrier runways, 8/26 (9400 feet long) and 14/32 (8000 feet long) and two general aviation runways, 9/27 and 13/31. Both of the general aviation runways are 2000 foot segments of the parallel taxiways to the respective air carrier runways. The twc air carrier runways do not cross; the 8 and 14 ends each begin about 2000 feet from the point where the two runways would cross if they were extended. The terminal area is located between the two runways, nearer the 8 and 14 ends. The preferred runway configuration for air carrier operations during good visibility conditions is to arrive on R26 and depart on R14. In low visibility conditions, arrivals use R8 and departures use R14 because R8 is the only runway that is presently instrumented for CAT II operations.

There are presently only one local controller and one ground controller.

The taxiway configuration is well designed with two parallel taxiways for each runway, easily permitting a one-way flow of traffic. Each runway has three angled turnoffs in either direction.

There are, at present, 40 air carrier gates, two of which can accommodate jumbo jets. The resulting gate capacity should suffice for at least 20 years.

3.4.2 Future Facilities and Operations

The first runway improvements at IAH will be to extend R14/32 and R8/26 in respective order. The extension of R14/32 to 12,000 feet and overlaying the existing runway is presently under construction and the same should be accomplished for R8/26 by 1978. A new 12,000 foot, 200 foot wide runway, R8R/26L, is planned for 1983. The new runway will be 6000 feet south of the present 8/26 runway.

The gates are planned to grow to 45 air carrier gates by 1975 and to 60 by 1980. Twenty of the 60 gates will be for jumbo jets. This expansion should easily accommodate the projected demand even if the jumbos require a longer gate service time.

3.4.3 Deployment Time Phasing

The inputs to the deployment analysis for IAH are presented in Table 3-4 and the ASTC systems deployment time phasing is summarized in Figure 3-4. An ASDE can be justified for the ground controller in bad visibility in 1978. Based on communications workload and resulting delays, an ASE should not be required, at least through the turn of the century.

3.5 MINNEAPOLIS-ST. PAUL INTERNATIONAL AIRPORT (MSP)

The following summarizes the results of the ASTC deployment analysis at MSP.

TABLE 3-4
DEPLOYMENT ANALYSIS INPUTS: IAH

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
9.1	2.6	0700-2100	35	132 182	185 285	38	54

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S'(14,26)	93 103	65 72 103	90 115	35 68 115	40	64
FUTURE	S(8L),M(32,26L)	130 145	96 105 145	90 115	35 68 115	60	96

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

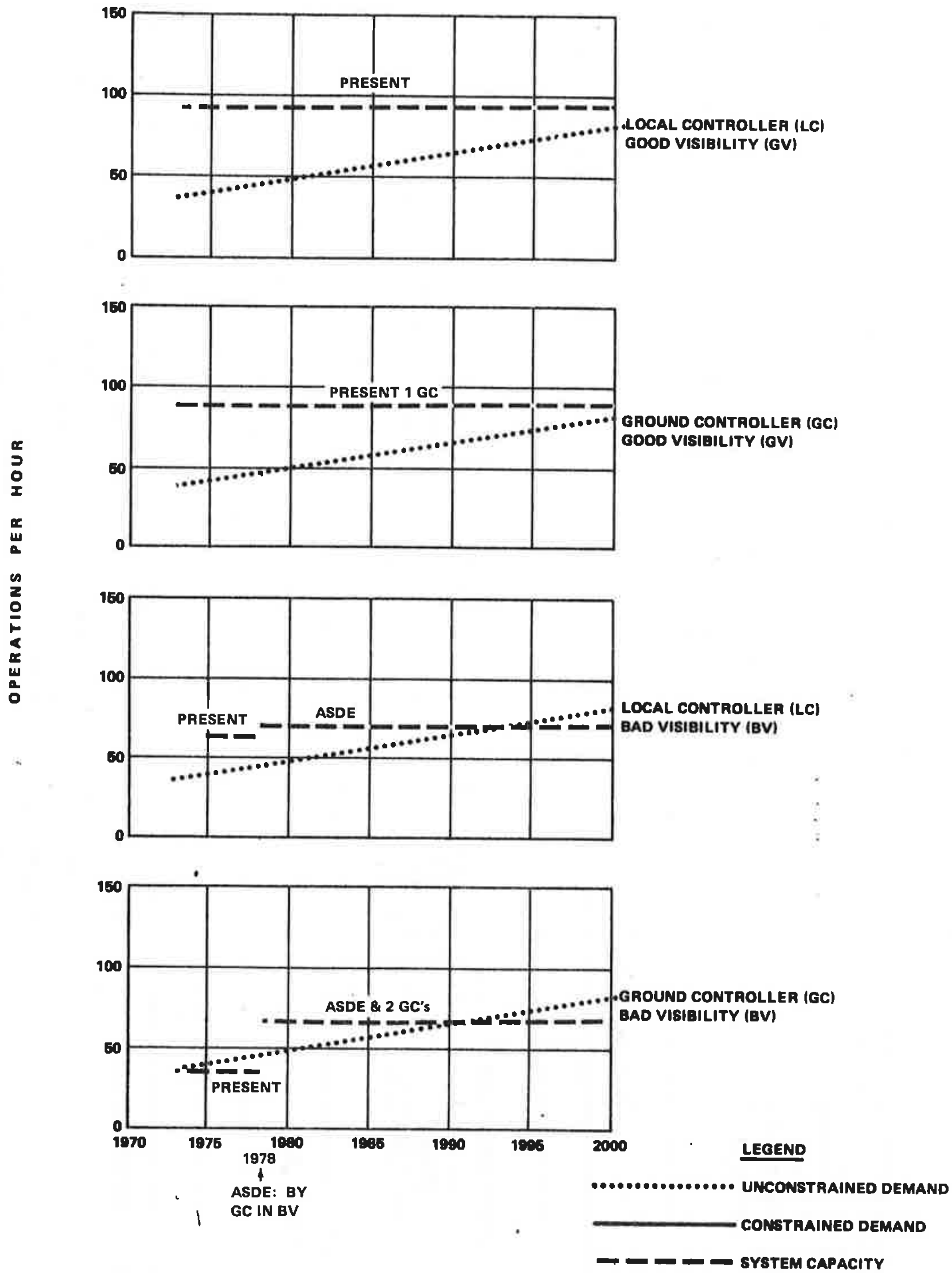

Figure 3-4. Houston Intercontinental Airport ASTC Systems Deployment

TABLE 3-5

DEPLOYMENT ANALYSIS INPUTS: MSP

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
1.9	2.6	0700-2300	35	118 177	253 317	43	60

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	D'(29L,R)	86 96	58 65 96	90 115	35 68 115	37	59
FUTURE	- - - - - - - - S A M E	A S	A B O V E	- - - - - -	- - - - - -	53	85

(1) RUNWAY CONFIGURATION:

S - SINGLE, MIXED

S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.

D - DUAL LANE.

D' - DÚAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.

F - FAR-END CROSSING.

N - NEAR-END CROSSING.

M - MID CROSSING.

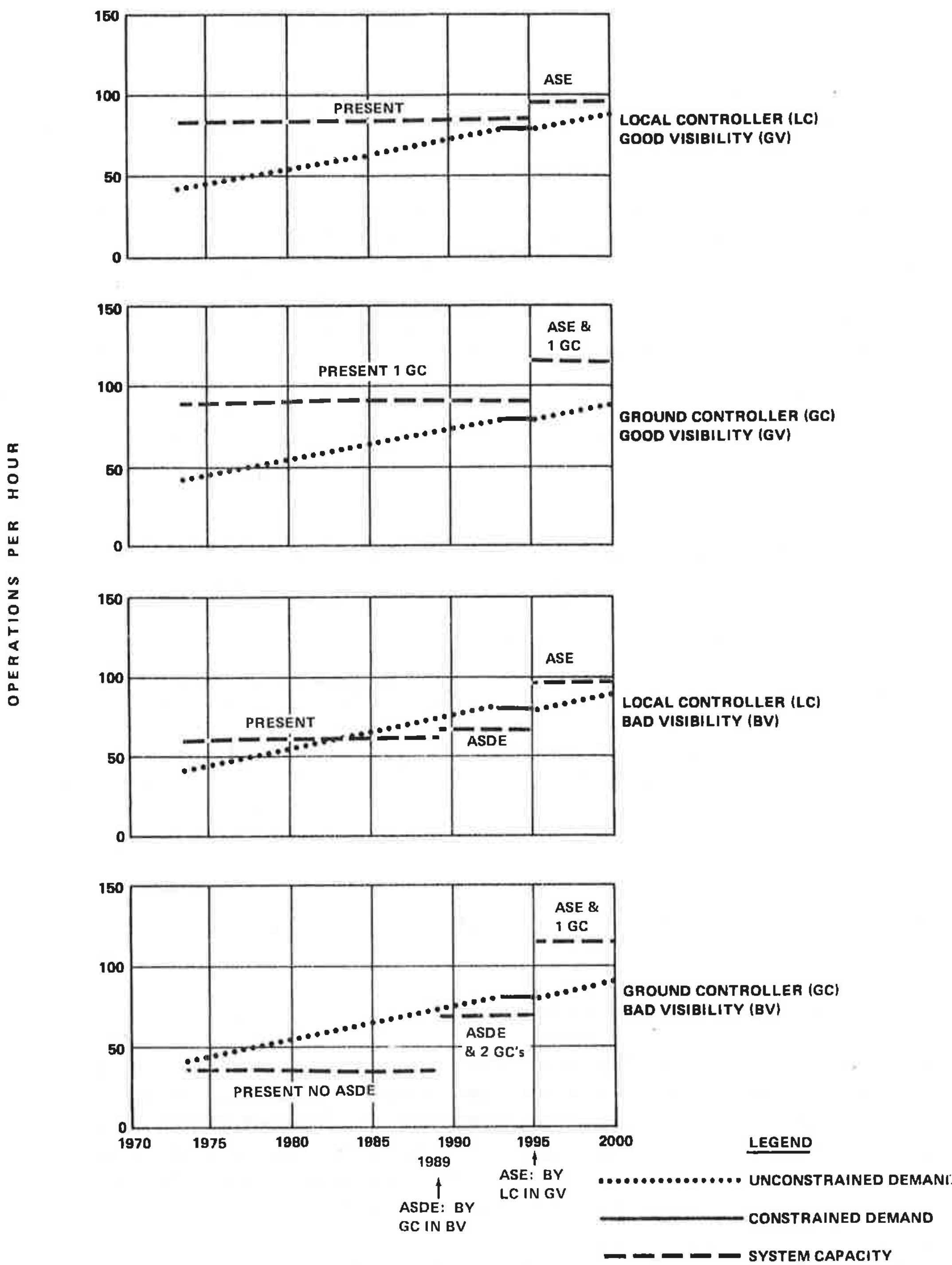

Figure 3-5. Minneapolis-St. Paul International Airport ASTC Systems Deployment

3.5.1 Present Facilities and Operations

The present runway configuration at MSP consists of three runways: a set of dual lanes, 11/29 L and R (R11R/29L is 10,000 feet long and R11L/29R is 8200 feet long); and a general aviation crossing runway, 4/22 which is also about 8200 feet long. The crossing runway crosses both dual lane runways, which are separated by about 3500 feet. The terminal area is located in between the dual lane runways. The preferred runway configuration for air carrier peak hours is: arrivals on R29L and departures on R29L and R. There are minor noise restrictions that require departures on R4, R29R and R11R to maintain runway headings until a specified altitude is reached before turning.

The taxiway system is adequate to establish one-way traffic flow patterns.

The present gate complex consists of 37 air carrier gates, of which 6 can accommodate jumbo jets. The resulting gate capacity is sufficient to handle the present and near future demand.

3.5.2 Future Facilities and Operations

There are no plans to expand the air carrier runway configuration at MSP. A new parallel utility runway, 4L/22R, with parallel and connecting taxiways is planned. The general aviation runway is planned to be only 3200 feet in length and will be located 1600 feet northwest of the existing 4/22 runway and south of runway 11R/29L.

An upper limit on the gate expansion is a total of 53 air carrier gates by 1980, of which 10 will accommodate jumbo jets, and an ultimate total of 120 gates.

3.5.3 Deployment Time Phasing

The inputs to the deployment analysis for MSP are presented in Table 3-5 and the ASTC systems deployment time phasing is summarized in Figure 3-5. An ASDE can be justified for the ground controller in bad visibility by 1984, and an ASE can be justified for the local controller in good visibility conditions by 1995 to meet the peak hour demand.

3.6 NEW ORLEANS INTERNATIONAL AIRPORT (MSY)

The following summarizes the results of the ASTC deployment analysis at MSY.

3.6.1 Present Facilities and Operations

The present runway configuration at MSY consists of three runways: two air carrier runways that cross at right angles, R10/28 that is 9200 feet long and R1/19 that is 7000 feet long; and a general aviation runway, 5/23 (4500 feet long), that crosses both air carrier runways. The preferred runway configuration during air carrier peak hours is: arrivals on R10 and departures on R19 to form a far end crossing configuration.

The taxiway system is adequate to establish a one-way traffic flow pattern when the above preferred runway configuration is used.

The present gate complex consists of 22 air carrier gates which should suffice for a few years.

3.6.2 Future Facilities and Operations

Plans are now being contemplated to build a new airport at New Orleans. However, if the plans do not materialize, a new parallel to R10/28 will be considered, which should easily provide sufficient runway capacity to meet projected demands through this century.

The gate complex is also planned to be increased to 42 air carrier gates, if the new airport is not built. The resulting gate capacity would also be sufficient until at least 1990.

3.6.3 Deployment Time Phasing

The inputs to the deployment analysis for MSY are presented in Table 3-6 and the ASTC systems deployment time phasing is summarized in Figure 3-6. An ASDE can be justified for the ground controller in bad visibility by 1985, but it appears that an ASE cannot be justified for either controller until at least the turn of the centruy. However, the new runway will be required by about 1987 to increase runway capacity to meet the peak hour demand.

3.7 MEMPHIS INTERNATIONAL AIRPORT (MEM)

The following summarizes the results of the ASTC deployment analysis at MEM.

TABLE 3-6

DEPLOYMENT ANALYSIS INPUTS: MSY

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA) YEARLY FREQUENCY > THAN 90 MIN. DURATION	BAD VISIBILITY (CAT II & IIIA) AVERAGE DURATION (HOURS)	BUSY HOURS (TIME OF DAY)	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000) 1973 AIR CARRIER TOTAL	DEMAND ANNUAL OPERATIONS (1000) 1983 AIR CARRIER TOTAL	DAILY PEAK OPERATIONS PER HOUR 1973	DAILY PEAK OPERATIONS PER HOUR 1983
5.1	2.6	0600-2100	29	102 155	165 240	32	51

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY RWY/LC CAPACITY (OPH) GV PRESENT ASE	CONTROLLER CAPACITY RWY/LC CAPACITY (OPH) BV NO ASDE ASDE ASE	CONTROLLER CAPACITY GC CAPACITY (OPH) GV PRESENT ASE	CONTROLLER CAPACITY GC CAPACITY (OPH) BV NO ASDE ASDE ASE	GATES NUMBER	GATES CAPACITY (OPH)
1973	F(10.19)	65 72	50 54 72	90 115	35 68 115	22	35
FUTURE	S(10L), S(10R)	108 120	80 86 120	90 115	35 68 115	42	67

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

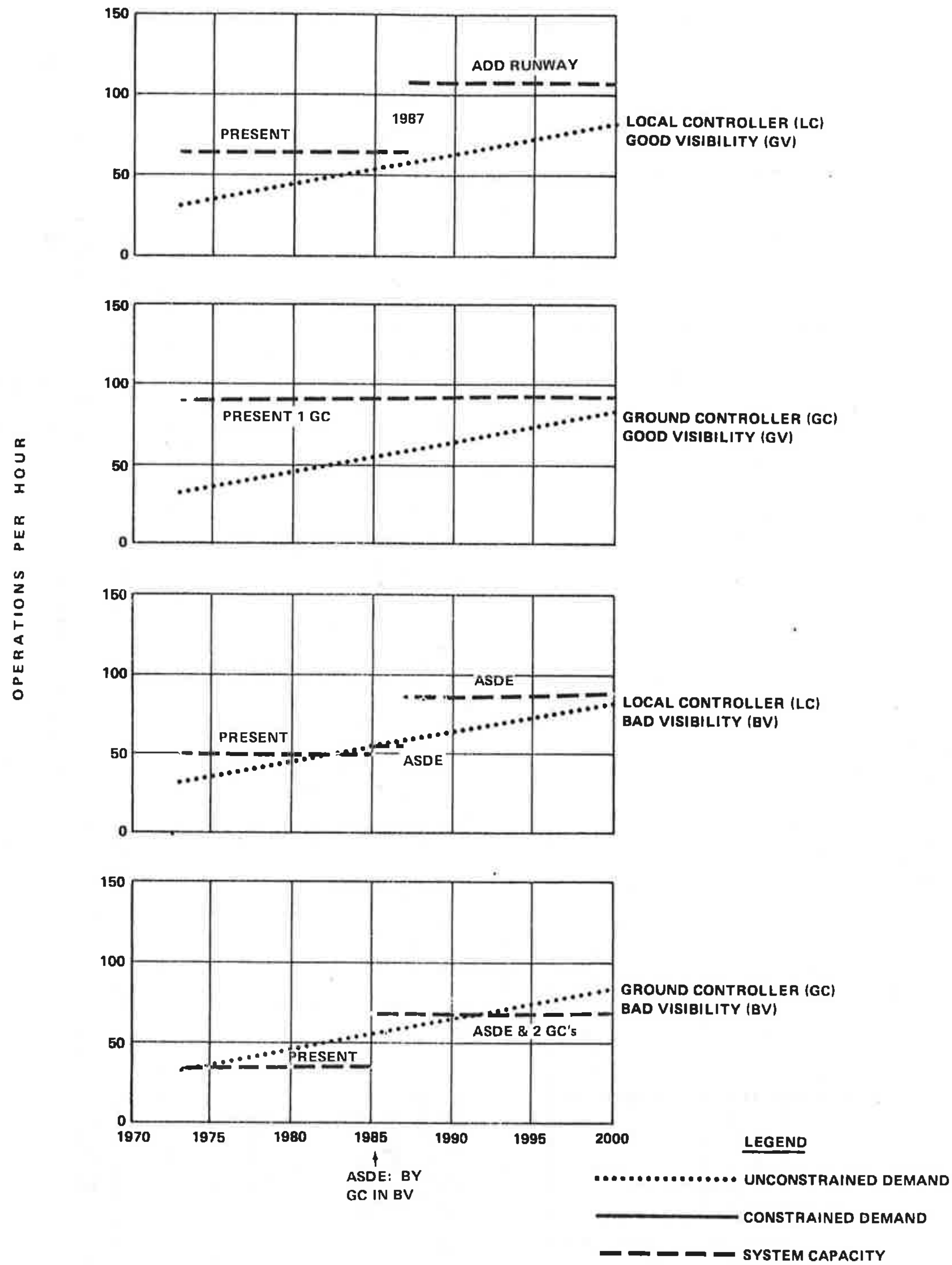

Figure 3-6. New Orleans International Airport
ASTC Systems Deployment

TABLE 3-7
DEPLOYMENT ANALYSIS INPUTS: MEM

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
2.1	2.4	0700-2100	25	99 293	142 407	35	49

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	D'(35L,R)	108 120	58 65 90	90 115	35 68 115	54	86
FUTURE	----- S A M E	A S A B O V E -----		138 175	35 68 175	58	93

(1) RUNWAY CONFIGURATION:

S - SINGLE, MIXED

S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.

D - DUAL LANE.

D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.

F - FAR-END CROSSING.

N - NEAR-END CROSSING.

M - MID CROSSING.

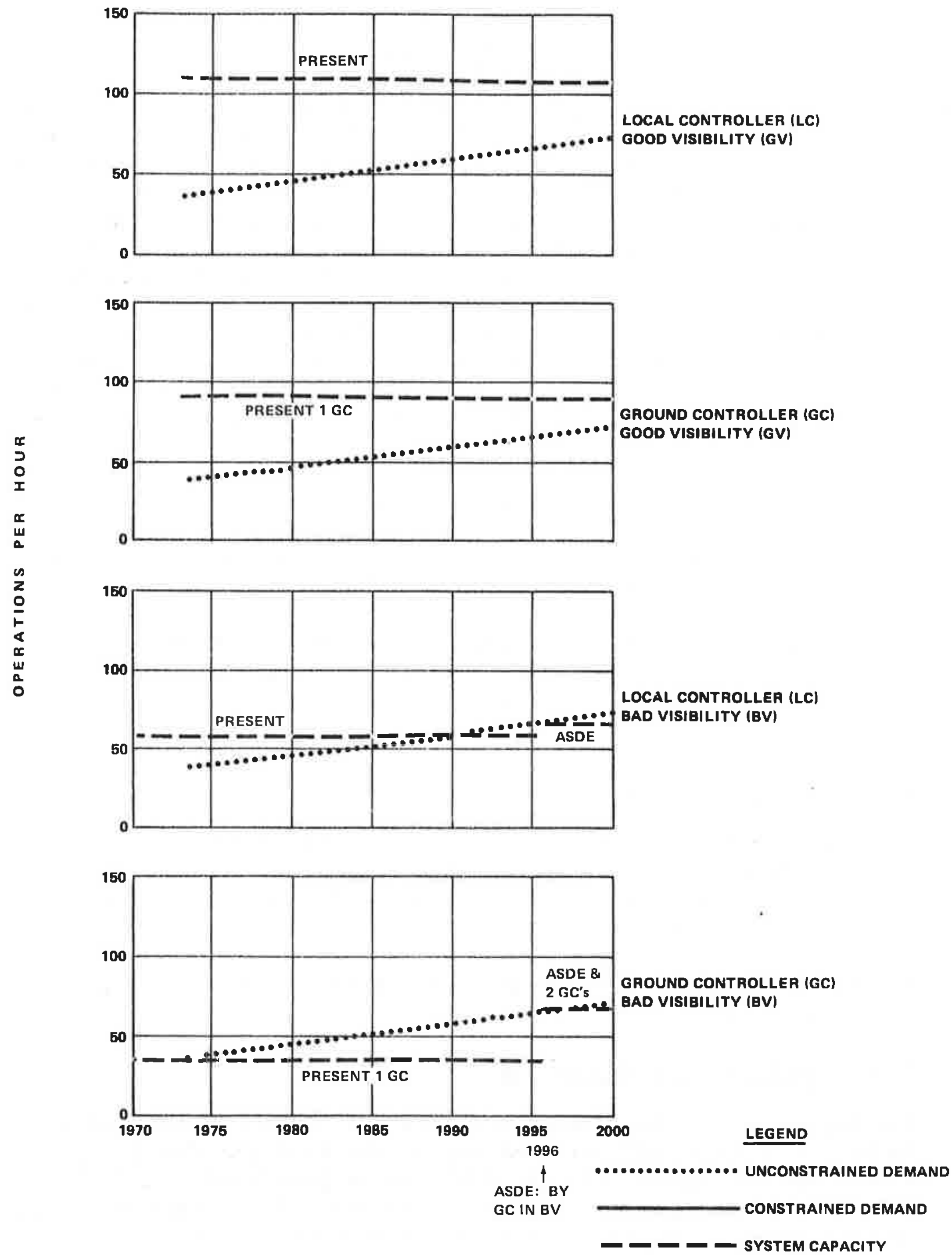

Figure 3-7. Memphis International Airport
ASTC Systems Deployment

3.7.1 Present Facilities and Operations

The present runway configuration at MEM consists of five runways: a set of dual lanes, 17L/35R (8400 feet long) and 17R/35L (9300 feet long), primarily for air carrier traffic with the terminal between the two runways (separated by 3500 feet); another air carrier runway, 9/27 (8900 feet long), to the north of the dual lanes; and two general aviation crossing runways, 14/32 and 3/21, that cross together at runway 9/27, forming three runways that cross at the same point. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is: arrivals and departures on both of the dual lanes, 17/35L and R. The only noise abatement restriction is on departures from R17R: a climb to 3,000 feet at the runway heading is required before turning.

The taxiway system is adequate to establish a one-way traffic flow pattern at present. However, the flow could be improved by an additional taxiway connecting the two terminals from the end of runway 3 to the end of runway 17R.

The present gate complex consists of 54 air carrier gates, of which 16 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic and the projected traffic for at least 20 years.

3.7.2 Future Facilities and Operations

There are no firm plans to expand the runway configuration at MEM. There are plans to upgrade the taxiway system by the addition of a new parallel taxiway to R9/27 and a cross over taxiway from R17R/35L to the west end of R9/27.

The gate complex will be expanded to 58 gates, of which 20 will accommodate jumbo jets.

3.7.3 Deployment Time Phasing

The inputs to the deployment analysis for MEM are presented in Table 3-7 and the ASTC systems deployment time phasing is summarized in Figure 3-7. An ASDE can be justified for the ground controller in bad visibility by 1996, but it appears that an ASE cannot be justified for either controller, at least through the end of the century.

3.8 KANSAS CITY INTERNATIONAL AIRPORT (MCI)

The following summarizes the results of the ASTC deployment analysis at MCI. The air carrier traffic at MCI has recently moved from

Kansas City Municipal Airport (MKC), hence some traffic data of record for MKC were used in the deployment analysis for MCI.

3.8.1 Present Facilities and Operations

The present runway configuration at MCI consists of only two runways, 1/19 (10,000 feet long) and 9/27 (9500 feet long). The two air carrier runways do not cross. They almost meet at the 1 and 9 ends where the terminal area is located between the two runways. The preferred runway configuration during peak periods is arrivals and departures on runways 19 and 27. In bad visibility conditions runways 1 and 9 are used because runway 1 is instrumented for CAT II operations.

The taxiway system is adequate to establish one-way traffic flows.

The present gate complex consists of 49 air carrier gates, of which 4 can accommodate jumbo jets. The resulting gate capacity should suffice to meet projected demands through this century.

3.8.2 Future Facilities and Operations

The planned runway expansions at MCI are extensive. Ultimately there will be four additional air carrier runways as follows: a parallel runway 3500 feet east of the existing runway 1/19, designated R1R/19L, 8600 feet long; another parallel runway 1400 feet west of the existing runway 1/19, designated R18L/36R, 10,800feet long; a third parallel runway 6200 feet west of the existing runway 1/19, designated R18R/36L, 15,100 feet long for long haul cargo jets; and a parallel runway 1400 feet south of the existing 9/27 runway, designated R9R/27L, 10,100 feet long. It is estimated that R1R/19L will be available by 1980, primarily for general aviation use, and the other runways will be available when required by necessary demand growth.

The gate complex will ultimately expand to 64 air carrier gates, of which 6 will accommodate jumbo jets. However, as for the runway expansions, the growth in gate capacity may not be necessary in the near future. There are three gate modules in the complex and each module was designed to handle two million enplaned passengers per year. At present the total demand is only about two million enplaned passengers per year.

3.8.3 Deployment Time Phasing

The inputs to the deployment analysis for MCI are presented in Table 3-8 and the ASTC systems deployment time phasing is summarized in Figure 3-8. An ASDE can be justified at MCI for

TABLE 3-8
DEPLOYMENT ANALYSIS INPUTS: MCI

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
9.2	3.4	0700-2400	36	119 170	157 257	39	53

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S'(19,27)	93 103	65 72 103	90 115	35 68 115	49	78
FUTURE	D(1L, 36R), S(1R, 19L)	140 150	105 115 150	90 115	35 68 115	64	102

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

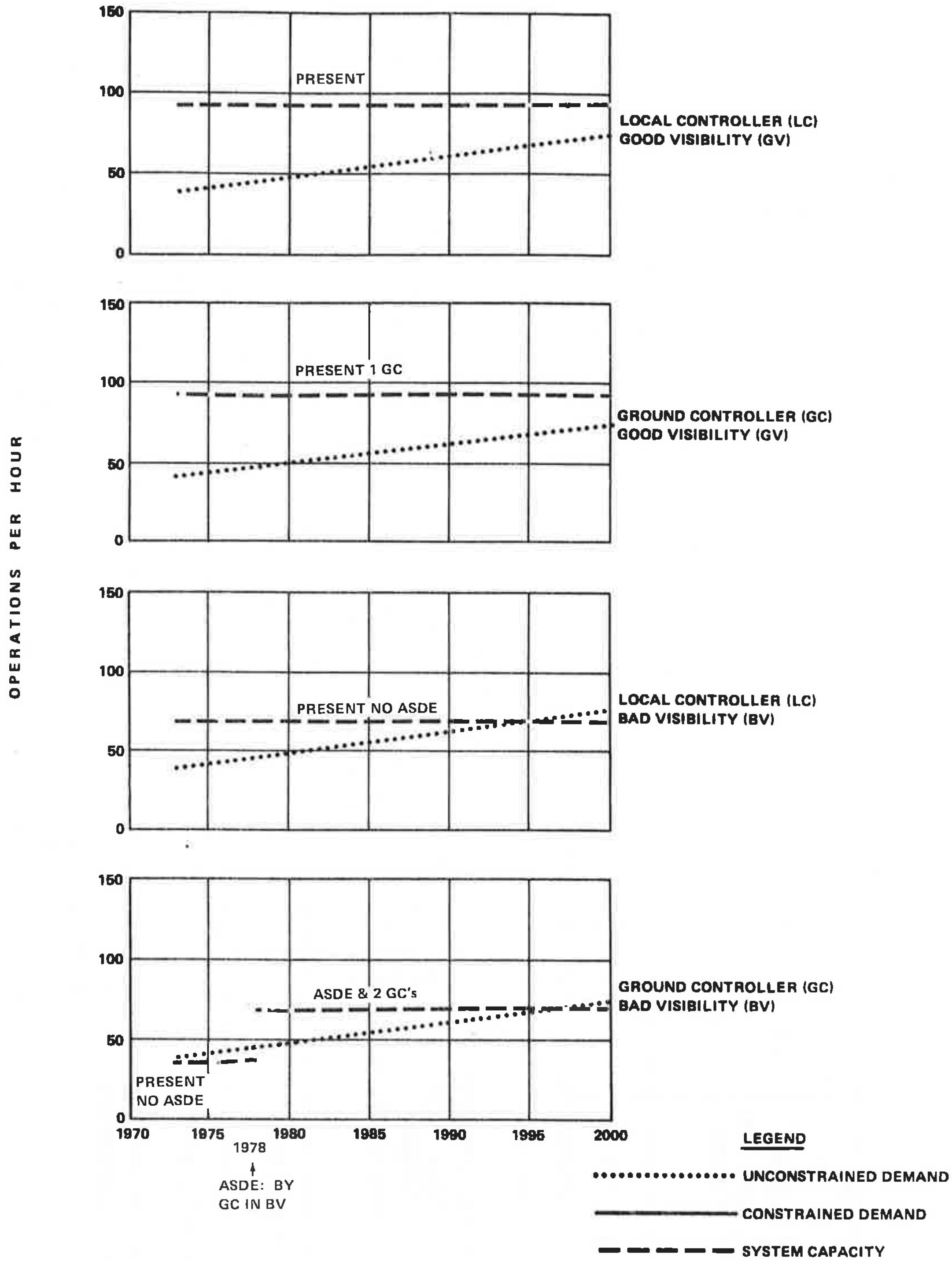

Figure 3-8. Kansas City International Airport ASTC Systems Deployment

TABLE 3-9

DEPLOYMENT ANALYSIS INPUTS: IND

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS (TIME OF DAY)	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)			1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
5.1	3.1	0700-2400	25	66 193	88 234	35	44

System Capacities

PERIOD	REPRESENTATIVE[(1)] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	M(22R, 31L)	76 85	56 62 85	90 115	35 68 115	20	32
FUTURE	S(4L), S(4R)	108 120	80 86 120	90 115	35 68 115	44	70

(1) RUNWAY CONFIGURATION:
- S - SINGLE, MIXED
- S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
- D - DUAL LANE.
- D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
- F - FAR-END CROSSING.
- N - NEAR-END CROSSING.
- M - MID CROSSING.

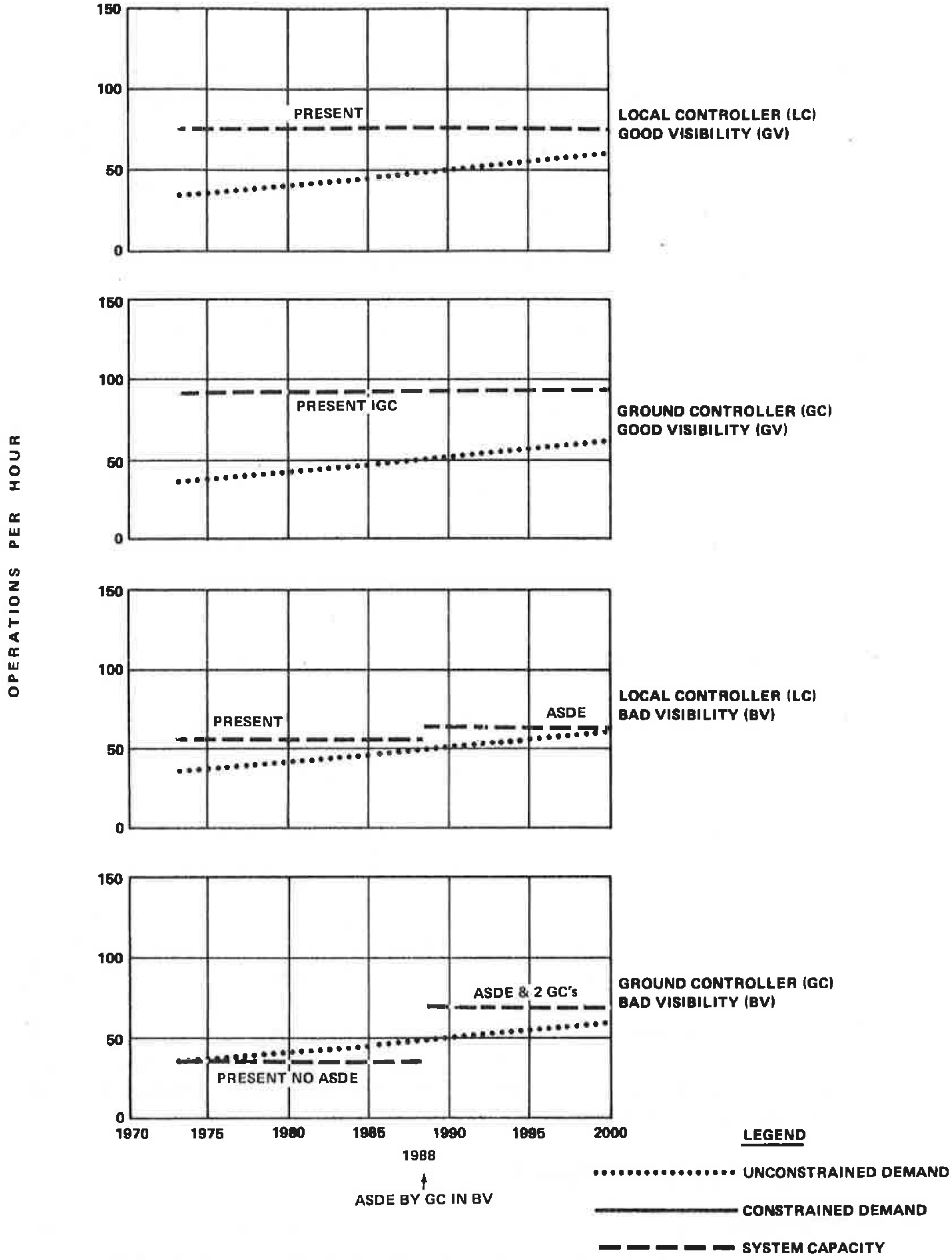

Figure 3-9. Indianapolis Municipal Airport ASTC Systems Deployment

the ground controller in bad visibility by 1978. It must be pointed out, however that bad visibility data for MCI did not exist, so, the data used were from MKC. Since the new airport, MCI, is in a new location, the incidence of bad visibility may not be as frequent. It appears that an ASE will not be required through the end of this century.

3.9 INDIANAPOLIS MUNICIPAL AIRPORT (IND)

The following summarizes the results of the ASTC deployment analysis at IND.

3.9.1 Present Facilities and Operations

The present runway configuration at IND consists of three runways: two crossing air carrier runways, 4L/22R (10,000 feet long) and 13/31 (7600 feet long); and a general aviation runway, 4R/22L (3700 feet long). The preferred runway configuration during air carrier peak periods is arrivals on R31 and departures on R22R.

The taxiway system is adequate to establish one-way traffic flows.

The present gate complex consists of 20 air carrier gates, of which only one can accommodate jumbo jets. The resulting capacity should suffice until about 1980.

3.9.2 Future Facilities and Operations

The additional runways that are ultimately planned for IND are: a new 4R/22L (7500 feet long), located 3500 feet southeast of the present 4L/22R runway; and a second 4/22 parallel (10,000 feet long) 2500 feet northwest of the present 4L/22R runway.

The gate complex is planned to be expanded ultimately to 44 gates, of which 4 will accommodate jumbo jets. By 1985 there should be 35 total gates, which should accommodate the demand through the end of this century.

3.9.3 Deployment Time Phasing

The inputs to the deployment analysis for IND are presented in Table 3-9 and the ASTC systems deployment time phasing is summarized in Figure 3-9. An ASDE cannot be justified until about 1988 for the ground controller in bad visibility and an ASE cannot be justified at least through the end of the century.

3.10 GREATER CINCINNATI AIRPORT (CVG)

The following summarizes the results of the ASTC deployment analysis at CVG.

3.10.1 Present Facilities and Operations

The present runway configuration at CVG consists of three runways: a set of dual lanes, 9L/27R (550 feet long) and 9R/27L (7800 feet long), of which R9R is primarily for air carrier traffic and R9L is a general aviation runway, and another air carrier runway 18/36 (9500 feet long), that crosses the dual lanes about in the middle. The dual lane runways are separated by about 1800 feet. The terminal area is located north of the dual lane set and to the west of R18/36. The preferred runway configuration during air carrier peak periods is: arrivals and departures on both of the dual lanes, 9/27L and R.

The taxiway system is adequate to establish a one-way traffic flow pattern at present.

The present gate complex consists of 18 air carrier gates, of which none can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic.

3.10.2 Future Facilities and Operations

The only major runway addition planned is a new runway parallel to the present R18/36. The new runway will be located on the other side of the terminal area from R18/36, 6000 feet from the existing runway about 1500 feet out from the approach end of R27L.

The gate complex is expected to grow to a total of 24 gates, of which 4 will accommodate jumbo jets, by 1980 and ultimately to a total of 36 gates, of which 8 will accommodate jumbo jets.

3.10.3 Deployment Time Phasing

The inputs to the deployment analysis for CVG are presented in Table 3-10 and the ASTC systems deployment time phasing is summarized in Figure 3-10. It appears that neither an ASDE nor an ASE will be required through the end of this century.

TABLE 3-10
DEPLOYMENT ANALYSIS INPUTS: CVG

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
6.1	2.7	0700-2300	24	83 151	92 209	28	34

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	D'(27L,R)	86 96	58 65 96	90 115	35 68 115	18	29
FUTURE	S(18L),S(18R)	108 120	80 86 120	90 115	35 68 115	36	58

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

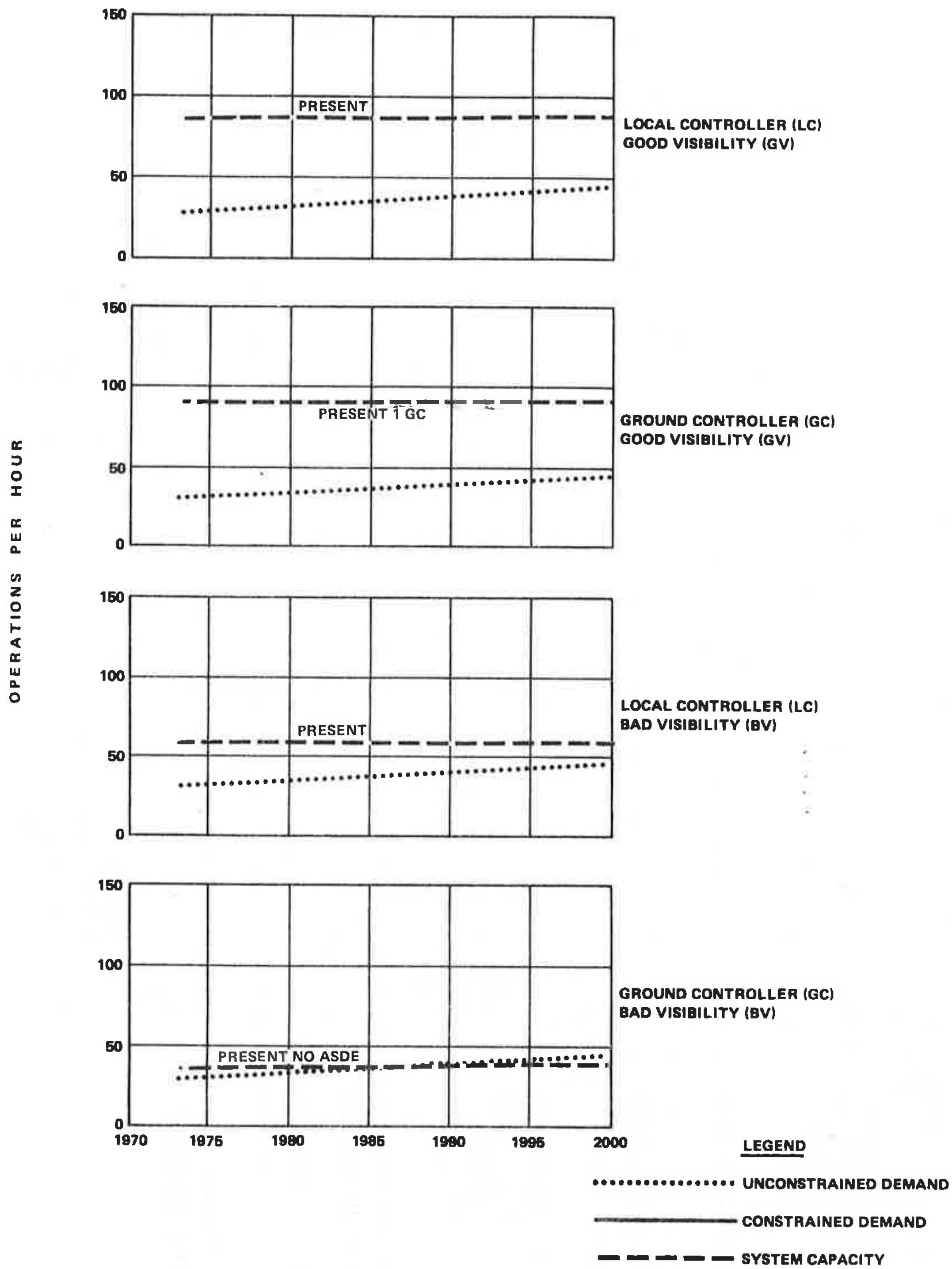

Figure 3-10. Greater Cincinnati Airport ASTC Systems Deployment

TABLE 3-11
DEPLOYMENT ANALYSIS INPUTS: PDX

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
9.3	3.2	0700-2200	19	77 174	117 229	24	35

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	D'(10L and R)	108 120	58 65 120	90 115	35 68 115	26	42
FUTURE	- - - - - - - - S A M E	A S	A B O V E -	- - - - - -	- - - - - -	- - - - - -	- - - - -

(1) RUNWAY CONFIGURATION:
- S - SINGLE, MIXED
- S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
- D - DUAL LANE.
- D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
- F - FAR-END CROSSING.
- N - NEAR-END CROSSING.
- M - MID CROSSING.

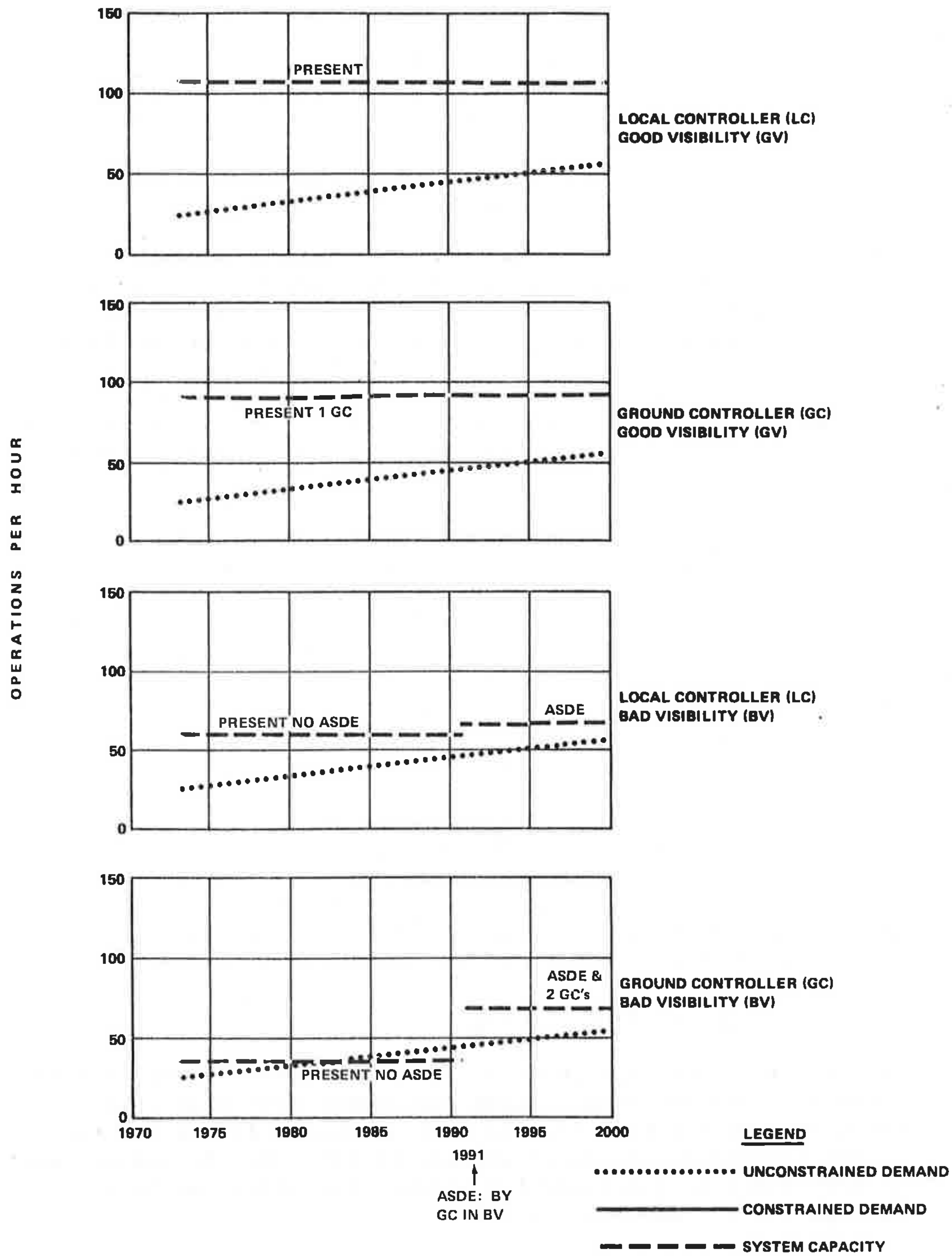

Figure 3-11. Portland International Airport ASTC Systems Deployment

3.11 PORTLAND INTERNATIONAL AIRPORT (PDX)

The following summarizes the results of the ASTC deployment analysis at PDX.

3.11.1 Present Facilities and Operations

The present runway configuration at PDX consists of three runways: a set of dual lanes, 10L/28R (8000 feet long) and 10R/28L (8800 feet long), primarily for air carrier traffic with the terminal between the two runways (separated by 3500 feet) and another air carrier runway, 2/20 (7000 feet long), located to the northwest of the terminal area and crossing R10L. The only noise abatement restriction is on R2/20, on which operations are restricted for jet aircraft and for other aircraft over 12,500 lbs gross weight.

The taxiway system is not adequate to establish a one-way traffic flow pattern at present. However, it does not appear to be a problem during normal operations. The magnitude of the traffic does not warrant the additional pavement at this time. An ASDE is installed at PDX but is not at present in use.

The present gate complex consists of 26 air carrier gates, of which 6 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic and the projected traffic for at least 10 years.

3.11.2 Future Facilities and Operations

There appears to be no plans to significantly change PDX. The only change in the near future may be a 2200 foot westerly extension to R10R.

3.11.3 Deployment Time Phasing

The inputs to the deployment analysis for PDX are presented in Table 3-11 and the ASTC systems deployment time phasing is summarized in Figure 3-11. An ASDE can be justified for the ground controller in bad visibility by 1991, but it appears that an ASE cannot be justified for either controller, at least through the end of this century.

3.12 SAN DIEGO INTERNATIONAL-LINDBERGH FIELD (SAN)

The following summarizes the results of the ASTC deployment analysis at SAN.

3.12.1 Present Facilities and Operations

The present runway configuration at SAN consists of only two runways: an air carrier runway, 9/27 (9400 feet long); and a general aviation runway, 13/31 (4400 feet long). The two runways form a near end crossing at the 27 and 31 ends of the two runways. The terminal area is located to the south of R9/27. The preferred runway configuration for all air carrier operations is, of course, the single runway, 9/27, for arrivals and departures. The only noise abatement limitation requires noise abatement approaches on departures from R17R and departures after 10 p.m.

The taxiway system is adequate to establish a one-way traffic flow pattern at present.

The present gate complex consists of 17 air carrier gates, of which 4 can accommodate jumbo jets. The resulting capacity appears barely sufficient to accommodate the present traffic.

3.12.2 Future Facilities and Operations

The only runway addition for SAN that is planned is a new 9/27 runway located about 1200 feet to the north of the present runway 9/27. The time frame for the new runway is considered long range, at least beyond 1980.

The gate complex is expected to be expanded by 8 jumbo jet gates to yield a total of 25 air carrier gates, of which 12 will accommodate jumbo jets.

3.12.3 Deployment Time Phasing

The inputs to the deployment analysis for SAN are presented in Table 3-12 and the ASTC systems deployment time phasing is summarized in Figure 3-12. An ASDE can be justified for the ground controller in bad visibility by 1992, but it appears that an ASE cannot be justified for either controller until at least the turn of the century. However, the new runway will be required by about 1988 to increase runway capacity to meet the peak hour demand.

3.13 GREATER BUFFALO INTERNATIONAL AIRPORT (BUF)

The following summarizes the results of the ASTC deployment analysis at BUF.

TABLE 3-12
DEPLOYMENT ANALYSIS INPUTS: SAN

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
3.3	2.9	0700-2300	20	76 224	120 332	28	43

System Capacities

PERIOD	REPRESENTATIVE[(1)] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(9/27)	54 60	40 43 60	90 115	35 68 115	17	27
FUTURE	D(9L and R)	81 90	58 65 90	90 115	35 68 115	25	40

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

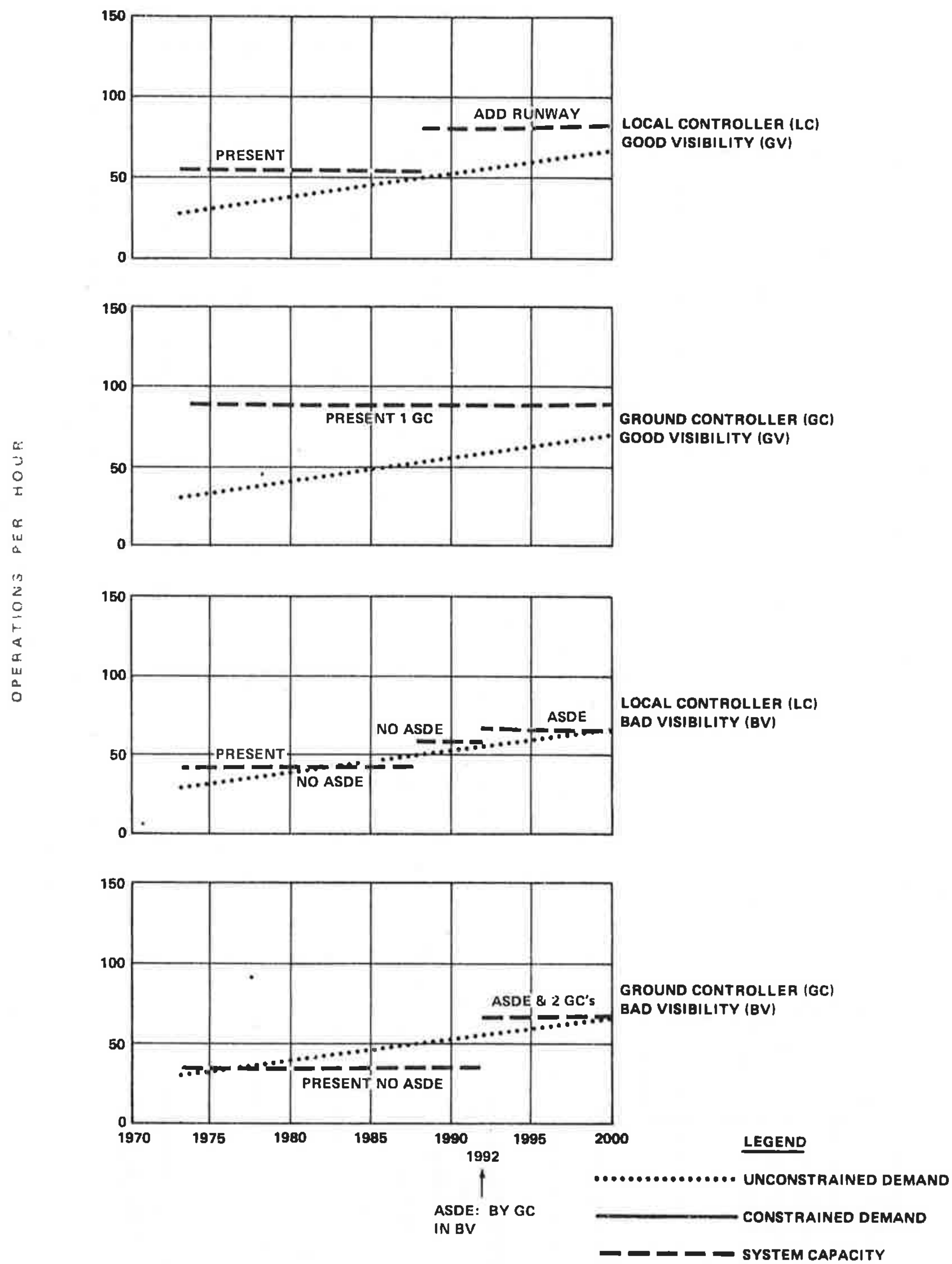

Figure 3-12. San Diego International-Lindbergh Field ASTC Systems Deployment

TABLE 3-13

DEPLOYMENT ANALYSIS INPUTS: BUF

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
6.7	2.4	0700-2200	22	63 166	75 236	29	37

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(23)	54 60	40 43 60	90 115	35 68 115	19	30
FUTURE	- - - - - - S A M	E A S	A B O V E - -	- - - - - -	- - -	47	75

(1) RUNWAY CONFIGURATION:

S - SINGLE, MIXED

S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.

D - DUAL LANE.

D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.

F - FAR-END CROSSING.

N - NEAR-END CROSSING.

M - MID CROSSING.

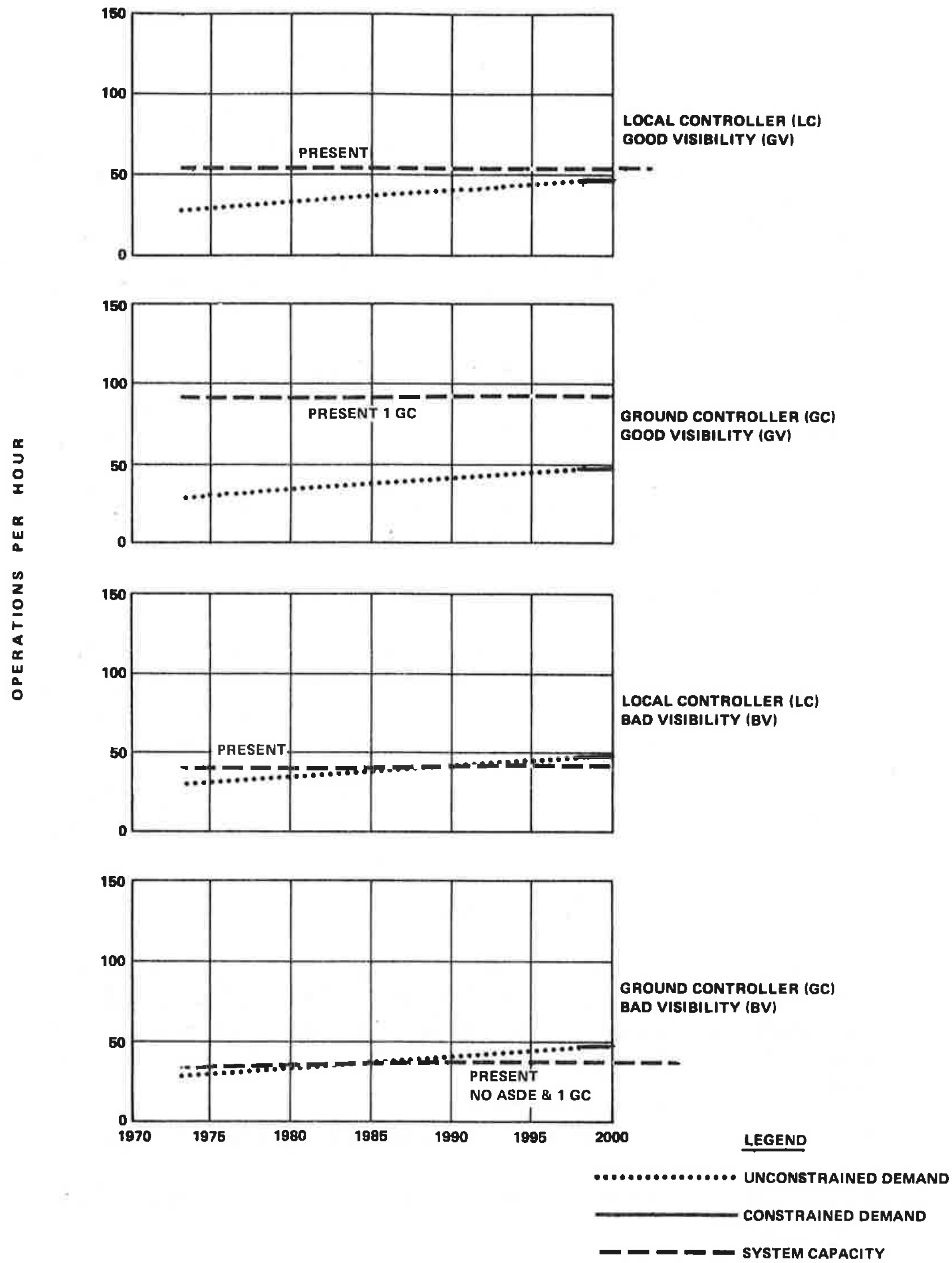

Figure 3-13. Greater Buffalo International Airport ASTC Systems Deployment

3.13.1 Present Facilities and Operations

The present runway configuration at BUF consists of two runways: the main air carrier runway, 5/23 (8100 feet long); and a second runway, 14/32, that is used for air carriers except heavy jets. The near end of R32 crosses in the middle of R5/23. The terminal area is to the southwest of this intersection. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is arrivals and departures on R23.

The taxiway system is adequate to establish a one-way traffic flow pattern at present for air carrier operations when the preferred runway configuration is used.

The present gate complex consists of 19 air carrier gates, of which only 2 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic.

3.13.2 Future Facilities and Operations

There are plans underway to build a new airport in the Buffalo area. If this plan does not materialize, then a new general aviation runway, 5L/23R (3300 feet long), will be constructed to the northwest of the present runway, 5/23. Also, the gates will be expanded to a total of 47 air carrier gates, of which 15 will accommodate jumbo jets. These expansions should easily accommodate expected demand growth through the end of this century.

3.13.3 Deployment Time Phasing

The inputs to the deployment analysis for BUF are presented in Table 3-13 and the ASTC systems deployment time phasing is summarized in Figure 3-13. It appears that neither an ASDE nor an ASE can be justified, at least through the end of this century.

3.14 GENERAL MITCHELL FIELD, MILWAUKEE, WISCONSIN (MKE)

The following summarizes the results of the ASTC deployment analysis at MKE.

3.14.1 Present Facilities and Operations

The present runway configuration at MKE consists of five runways: a set of dual lanes, 7L/25R (4200 feet long) and 7R/25L (8000 feet long), the latter primarily for air carrier traffic and the shorter one for general aviation traffic, with the terminal between the two runways (separated by about 4000 feet); another set of dual lanes, 1L/19R (9900 feet long) and 1R/19L (4200 feet long), the longer runway for air carrier operations and the shorter one for general aviation operations (separated by about 1000 feet); and a 5600 foot runway, 13/31 that can be used for air carrier except heavy jets. The preferred runway configuration for good visibility conditions during air carrier peak periods is: arrivals and departures on both of the dual lanes, R7/25, R7R/25L for air carriers and R7L/25R for general aviation operations.

The taxiway system is adequate to establish a one-way traffic flow pattern at present.

The present gate complex consists of 21 air carrier gates, of which 3 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic.

3.14.2 Future Facilities and Operations

The present plan for increasing the runway capacity of MKE is to extend runway 1R/19L on both ends to a total of 9500 feet. The set of dual lane runways, 1/19, will become the preferred air carrier runway configuration. Also, it is planned to construct a new parallel to runway 7L/25R, 5000 feet long.

The gate complex is expected to be expanded to a total of 24 air carrier gates in the near future, to 36 gates by about 1980 and ultimately to 47 gates. The resulting gate capacity should easily accommodate the air carrier demand as it is expected to grow.

3.14.3 Deployment Time Phasing

The inputs to the deployment analysis for MKE are presented in Table 3-14 and the ASTC systems deployment time phasing is summarized in Figure 3-14. An ASDE can be justified for the ground controller in bad visibility by 1985, but it appears that an ASE cannot be justified for either controller until at least the turn of the century. However, the new runway will be required by about 1987 to increase runway capacity to meet the peak hour demand.

3.15 DOUGLAS MUNICIPAL AIRPORT, CHARLOTTE, N.C. (CLT)

The following summarizes the results of the ASTC deployment analysis at CLT.

TABLE 3-14

DEPLOYMENT ANALYSIS INPUTS: MKE

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
11.6	2.8	0700-2100	22	68 219	99 290	32	44

System Capacities

PERIOD	REPRESENTATIVE PEAK HOUR RUNWAY CONFIGURATION (1)	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(1L)	54 60	40 43 60	90 115	35 68 115	21	34
FUTURE	D(1L and R)	81 90	58 65 90	90 115	35 68 115	36	58

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

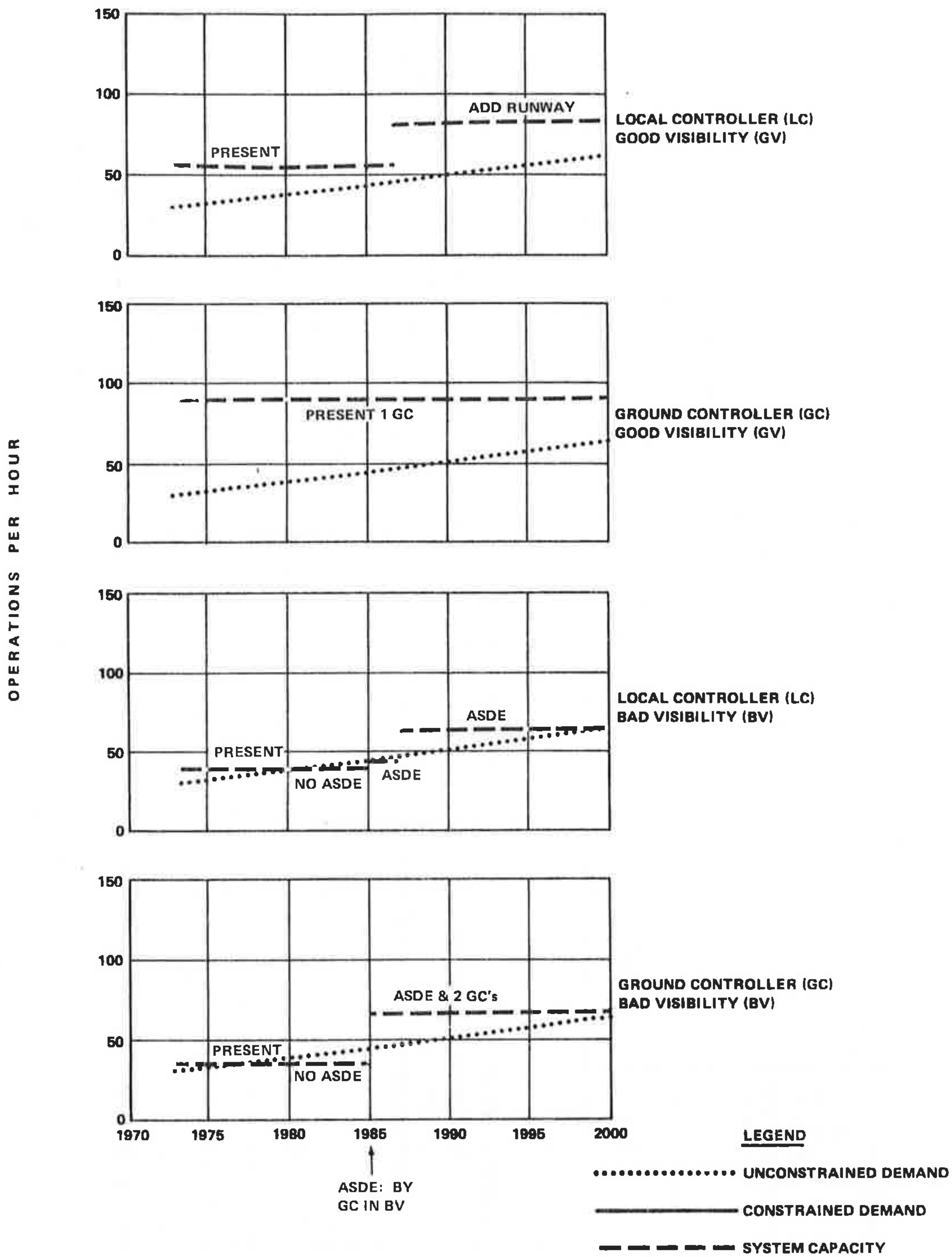

Figure 3-14. General Mitchell Field, Milwaukee, Wisconsin ASTC Systems Deployment

TABLE 3-15
DEPLOYMENT ANALYSIS INPUTS: CLT

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
6.1	2.5	0700-2300	16	60 168	76 231	22	28

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	F(5,36)	65 72	50 54 72	90 115	35 68 115	12	19
FUTURE	S(36L), S(36R)	108 120	80 86	90 115	35 68 115	39	62

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

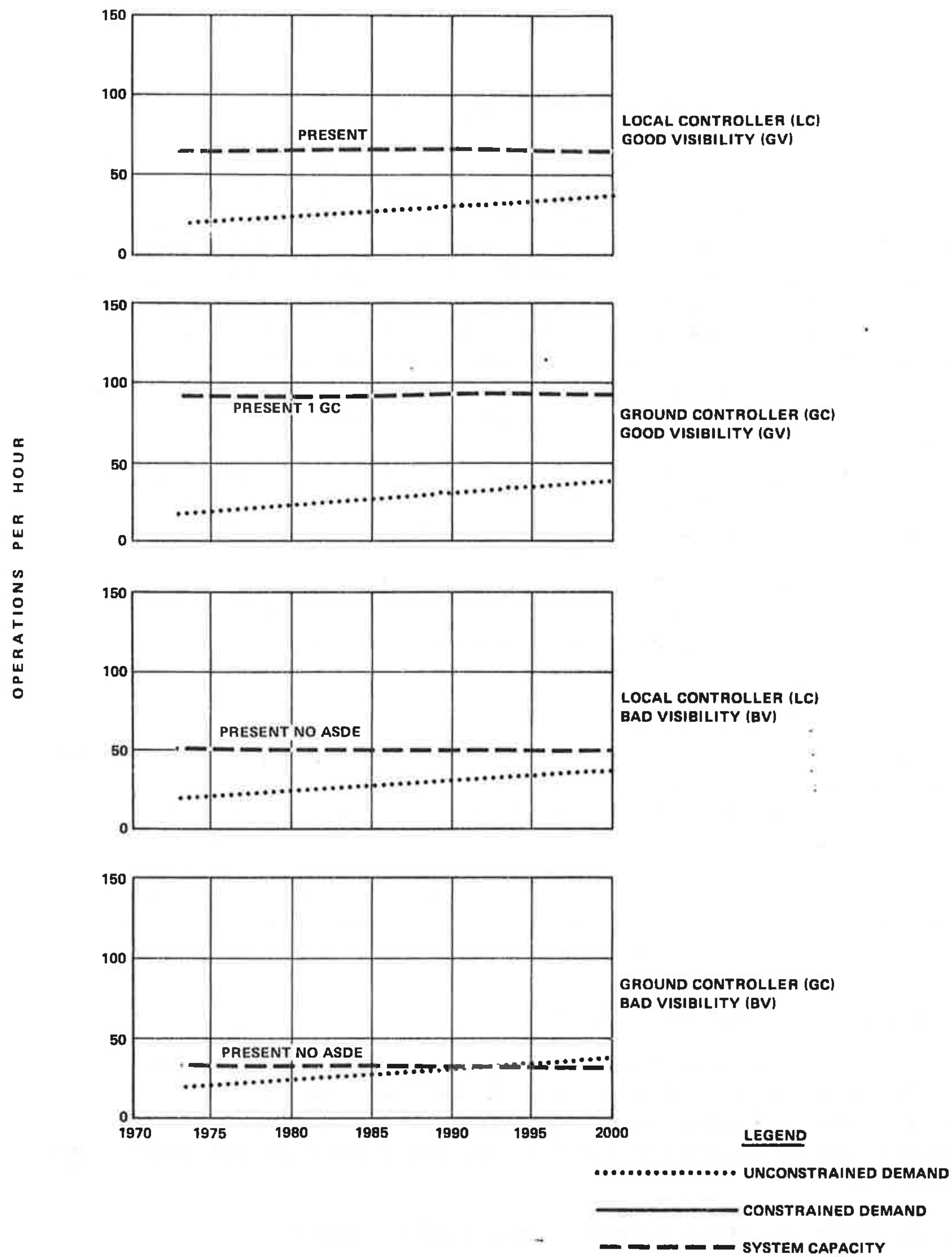

Figure 3-15. Douglas Municipal Airport, Charlotte, N.C.
ASTC Systems Deployment

3.15.1 Present Facilities and Operations

The present runway configuration at CLT consists of two runways: a 7800 foot air carrier runway, 18/36; and another air carrier runway, 5/23 (7500 feet long), that crosses the longer runway. They form a near end crossing at the 18 and 23 ends of the respective runways. The terminal area is located between R5 and R36 near the crossing. The preferred runway configuration for good visibility conditions during air carrier peak periods is: air carrier arrivals and departures on R5 and general aviation operations on R36. Runway 5 is also the preferred runway for bad visibility conditions since it is instrumented.

The taxiway system is not adequate to establish a one-way traffic flow pattern at present. However, the one-way flow could be obtained by additional parallel taxiways.

The present gate complex consists of 12 air carrier gates, of which none can accommodate jumbo jets. The resulting capacity appears barely sufficient to accommodate the present traffic.

3.15.2 Future Facilities and Operations

The planned runway improvement at CLT is a new precision instrument parallel runway to the present runway 18/36. The new parallel will be located to the west of the present R18/36. It is under construction now.

The gate complex is also to be expanded; from 12 to 25 gates before 1980 and to 39 gates ultimately. These expansions should easily accommodate the projected demand.

3.15.3 Deployment Time Phasing

The inputs to the deployment analysis for CLT are presented in Table 3-15 and the ASTC systems deployment time phasing is summarized in Figure 3-15. It appears that neither an ASDE nor an ASE can be justified for CLT, at least through the end of the century.

3.16 PORT COLUMBUS INTERNATIONAL AIRPORT (CMH)

The following summarizes the results of the ASTC deployment analysis at CMH.

3.16.1 Present Facilities and Operations

The present runway configuration at CLT consists of five runways: a set of dual lanes, 10R/28L (10,700 feet long) and 10L/28R (6000 feet long), the longer of which is primarily for air carrier traffic with the terminal between the two runways (separated by 2800 feet); and three general aviation crossing runways, 1/19, 5/23 and 13/31, forming three runways that cross at the same point at the 28L end of and to the south of R28L. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is: arrivals and departures on both of the dual lanes with the longer runway used primarily by air carriers.

During good visibility peaks, two local controllers are used.

The taxiway system is not adequate to establish a one-way traffic flow pattern at present. However, the flow could be attained by an additional taxiway connecting the two dual lane runways.

The present gate complex consists of only 15 air carrier gates, of which none can accommodate jumbo jets. The resulting capacity is most likely barely sufficient to accommodate the present traffic.

3.16.2 Future Facilities and Operations

The only runway improvement at CMH that is planned is to extend the shorter of the two dual lane runways by 1000 feet. There are several improvements expected on the taxiways and apron.

At present, any other improvements, expansions, etc., are not firm.

3.16.3 Deployment Time Phasing

The inputs to the deployment analysis for CMH are presented in Table 3-16 and the ASTC systems deployment time phasing is summarized in Figure 3-16. It appears that neither an ASDE nor an ASE can be justified for either controller through the turn of the century. However, the extension to the shorter dual lane runway will be required by about 1993 to increase runway capacity to meet the peak hour demand.

3.17 WASHINGTON-DULLES INTERNATIONAL AIRPORT (IAD)

The following summarizes the results of the ASTC deployment analysis at IAD.

TABLE 3-16
DEPLOYMENT ANALYSIS INPUTS: CMH

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
3.8	2.7	0700-2100	19	62 316	77 369	35	42

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(28L)	54 60	40 43 60	90 115	35 68 115	15	24
FUTURE	D(28L and R)	81 90	58 65 90	90 115	35 68 115	15	24

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

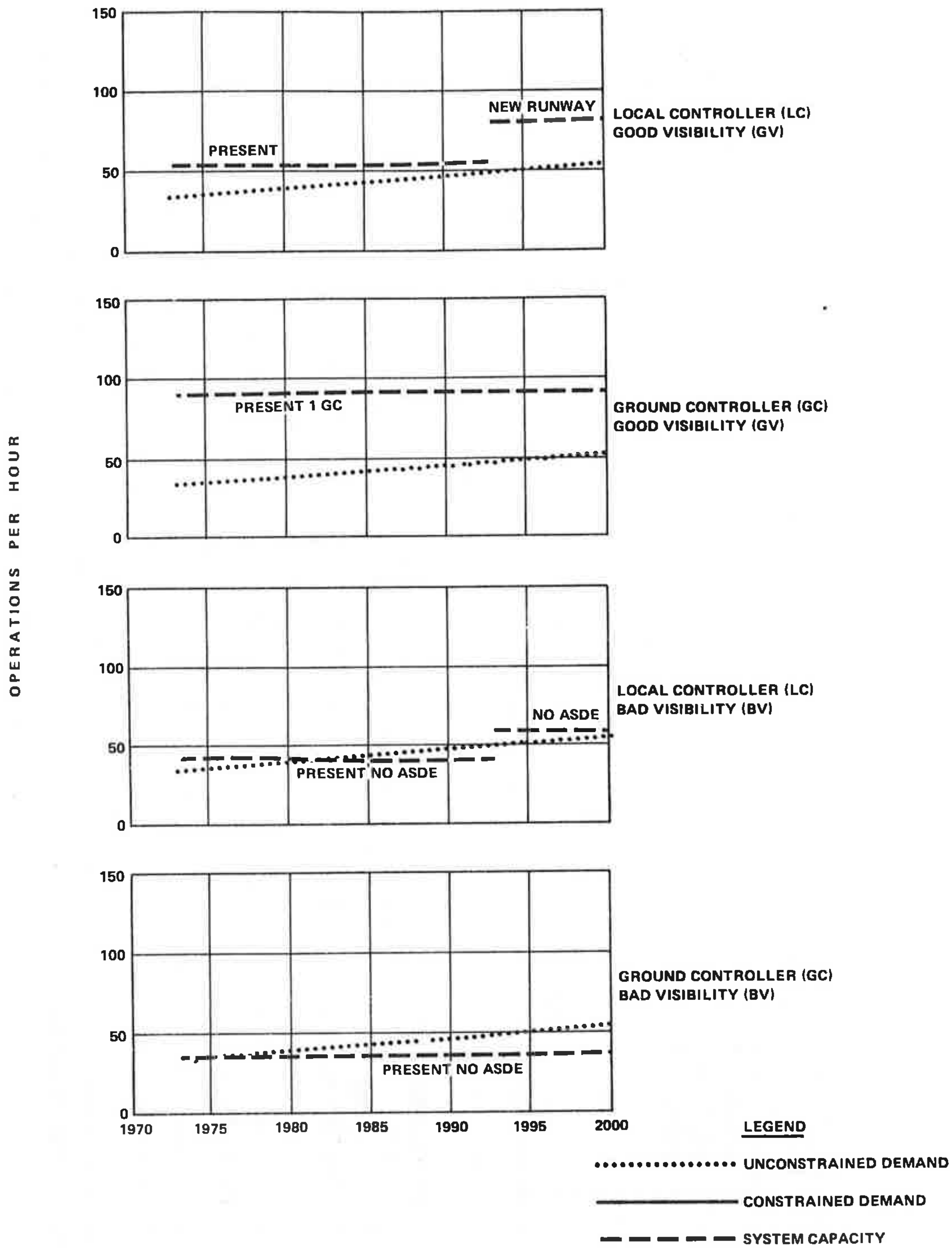

Figure 3-16. Port Columbus International Airport ASTC Systems Deployment

TABLE 3-17
DEPLOYMENT ANALYSIS INPUTS: IAD

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
2.6	3.9	0800-2200	17	62 186	111 267	24	39

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(1R), S(1L or 30)	93 103	65 72 103	90 115	35 68 115	40	64
FUTURE	- - - - - - - - S A M	E A S	A B O V E - -	- - - - - -	- - - - - -	106	170

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

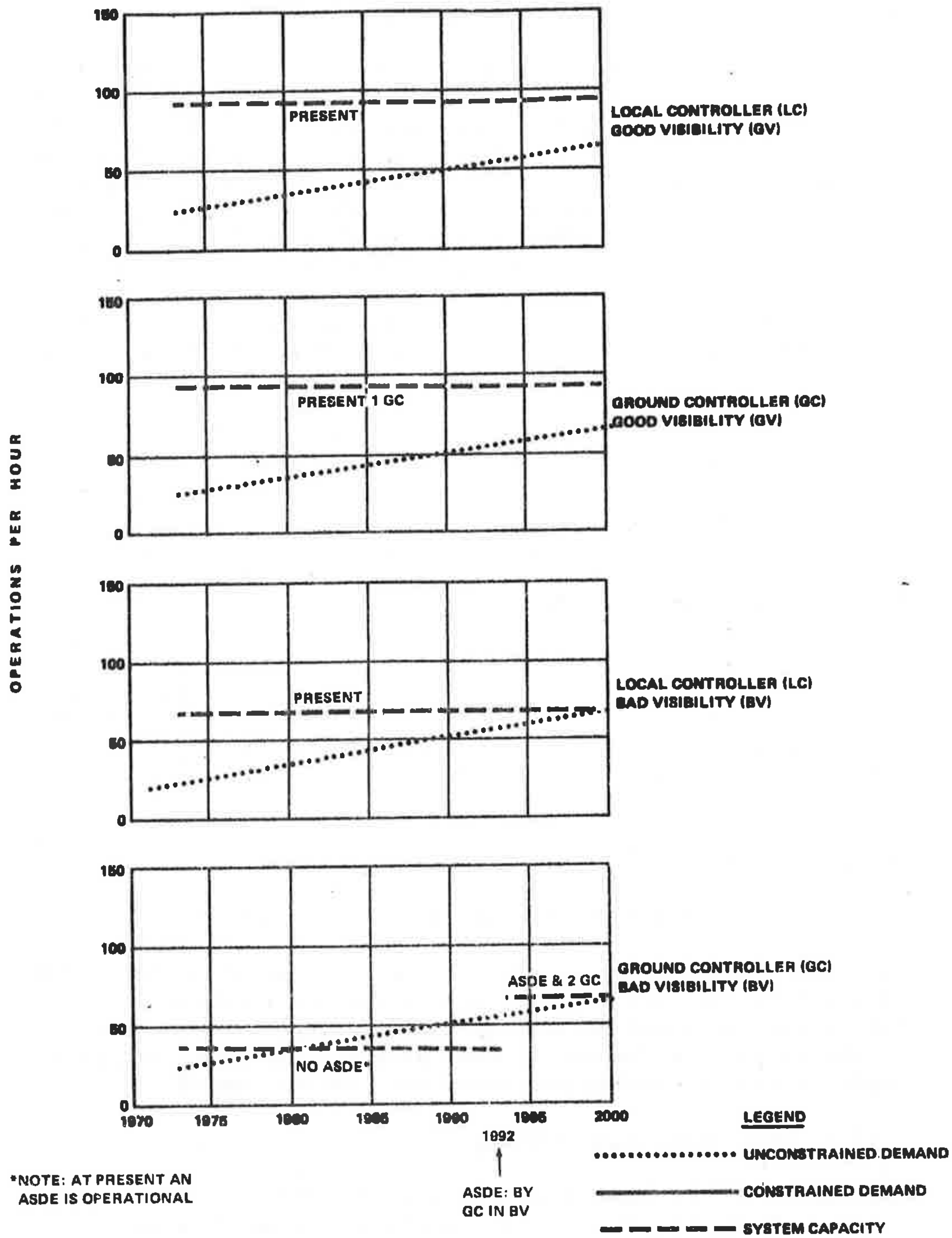

Figure 3-17. Washington-Dulles International Airport ASTC Systems Deployment

3.17.1 Present Facilities and Operations

The present runway configuration at IAD consists of three runways: a set of parallel runways, 1L/19R (11,500 feet long) and 1R/19L (11,500 feet long), primarily for air carrier traffic with the terminal between the two runways (separated by about 6800 feet); and another air carrier runway, 12/30 (10,000 feet long), to the west of the two parallels. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is: arrivals on R1R and departures on R1L and R30.

The taxiway system is adequate to establish a one-way traffic flow pattern at present. There is an ASDE installed and in use at IAD.

The present gate complex consists of 40 air carrier gates, of which 30 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic and the projected traffic for at least 20 years. The terminal complex is not designed as are most conventional air commerce airports. The complex is designed for the mobile lounge concept with the passenger gate at the terminal building and the aircraft gate at a service area dislocated from the terminal building. Passengers are transferred from the terminal building to the aircraft via the mobile lounge. The 40 air carrier gates are aircraft gates in the service area. Other airports have adopted this system of using hardstands for aircraft parking and bussing passengers out to the hardstands when the gate complex can no longer be expanded.

3.17.2 Future Facilities and Operations

There are no plans to expand the runway capacity at IAD.

The gate complex is expected to expand to a total of 55 by 1980, of which 45 will accommodate jumbo jets, and to a total of 106 ultimately, of which 90 will accommodate jumbo jets. These estimates include the use of hard stands. The resulting gate capacity easily exceeds projected air carrier demand.

3.17.3 Deployment Time Phasing

The inputs to the deployment analysis for IAD are presented in Table 3-17 and the ASTC systems deployment time phasing is summarized in Figure 3-17. An ASDE can be justified for the ground controller in bad visibility by 1993, but it appears that an ASE cannot be justified for either controller until at least the turn of the century. However, the ASDE is presently being used. A requirement, not considered in this study, is the additional controller workload created by the mobile lounge vehicles that must be controlled by the ground controller. This additional requirement is likely sufficient justification for an ASDE at present.

3.18 STANDIFORD FIELD, LOUISVILLE, KENTUCKY (SDF)

The following summarizes the results of the ASTC deployment analysis at SDF.

3.18.1 Present Facilities and Operations

The present runway configuration at SDF consists of three runways: a pair of crossing air carrier runways, 1/19 (7800 feet long) and 11/29 (7200 feet long), and a general aviation runway, 6/24 (5000 feet long) that crosses both air carrier runways. The two air carrier runways cross about in the middle with the terminal area located to the northeast of the crossing. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is: arrivals on R1 and departures on R11. This configuration is used as often as possible due to noise abatement considerations.

The taxiway system is adequate to establish a one-way traffic flow pattern at present.

The present gate complex consists of 25 air carrier gates, of which none can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic and the projected traffic for at least 20 years.

3.18.2 Future Facilities and Operations

The only plans for improving the runways at SDF is to strengthen runway 11/19.

The gate complex is expected to expand to a total of 29 gates in the near future, of which 2 will accommodate jumbo jets and to a total of 36 ultimately of which 2 will accommodate jumbo jets. The resulting gate capacity will easily handle the projected air carrier demand.

TABLE 3-18
DEPLOYMENT ANALYSIS INPUTS: SDF

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS (TIME OF DAY)	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)			1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
.18	2.7	0700-2300	17	66 149	73 191	21	25

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)			
		GV	BV	GV	BV	NUMBER	CAPACITY (OPH)
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	M(1,11)	76 85	56 62 85	90 115	35 68 115	25	40
FUTURE	--- SAME AS ABOVE --------------					36	58

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

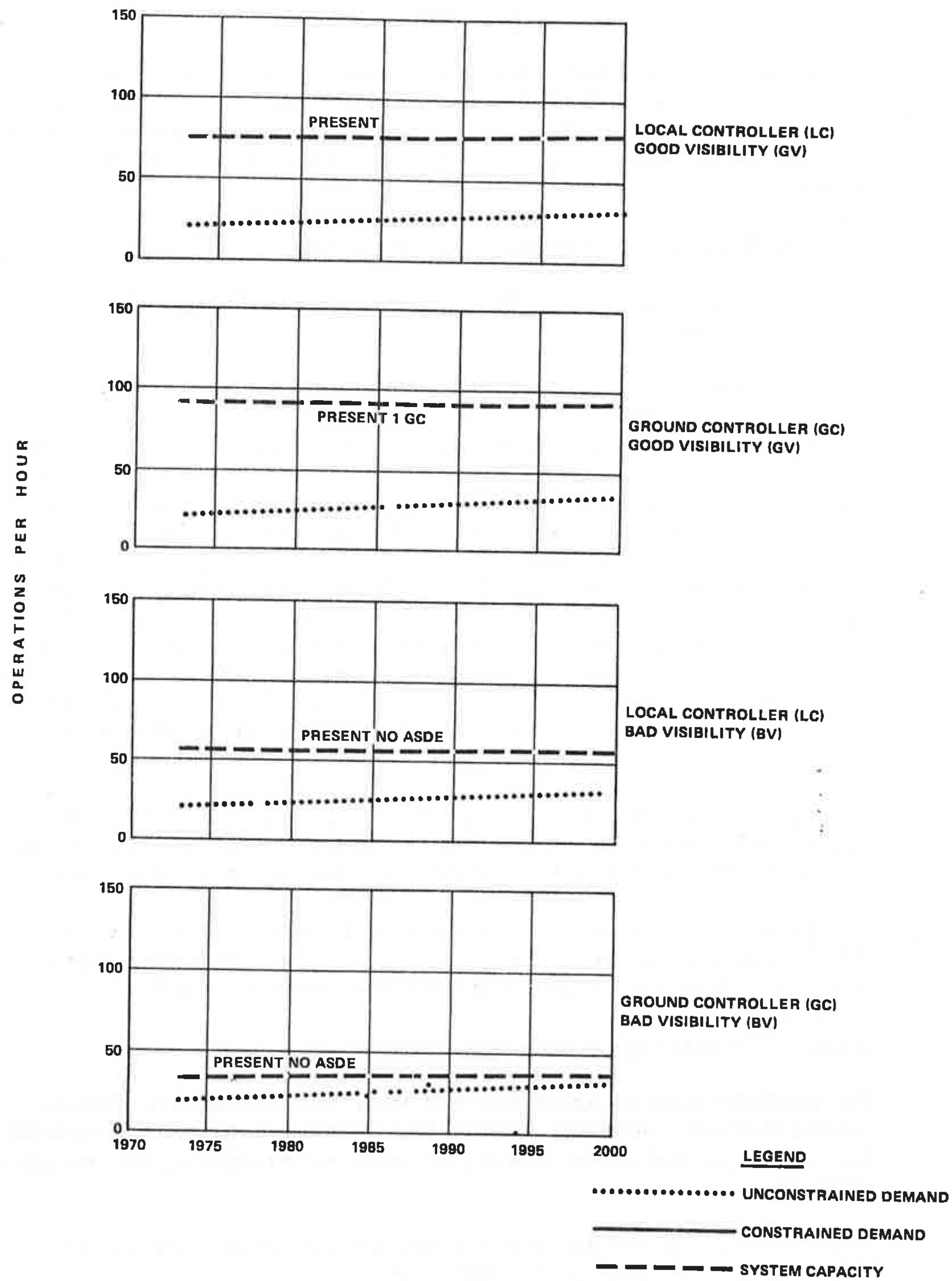

Figure 3-18. Standiford Field, Louisville, Ky.
ASTC Systems Deployment

3.18.3 Deployment Time Phasing

The inputs to the deployment analysis for SDF are presented in Table 3-18 and the ASTC systems deployment time phasing is summarized in Figure 3-18. It appears that neither an ASDE nor an ASE can be justified, at least through the end of this century.

3.19 COX DAYTON MUNICIPAL AIRPORT (DAY)

The following summarizes the results of the ASTC deployment analysis at DAY.

3.19.1 Present Facilities and Operations

The present runway configuration at DAY consists of three runways: a set of parallel runways, 6L/24R (9500 feet long) and 6R/24L (7000 feet long), primarily for air carrier traffic with the terminal between the two runways (separated by 5000 feet); and another air carrier runway, 18/36 (7000 feet long). The south end of R36 crosses R6R in the middle and extends north about 6000 feet. The preferred runway configuration for good visibility conditions during air carrier peak periods is: arrivals and departures on both of the parallel runways. Runway 24L is used primarily for general aviation operations. Approaches to R6L and R36 by air carriers are avoided due to noise abatement considerations.

The taxiway system is not adequate to establish a one-way traffic flow pattern at present. However, the flow can be attained by an additional parallel taxiway to R6L and into the ramp.

The present gate complex consists of 20 air carrier gates, of which none can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic.

3.19.2 Future Facilities and Operations

The improvements planned for DAY will not change the runway configuration. However, there are extensive plans to improve the taxiways and apron areas, as well as extending R6L by about 3000 feet.

At present, a planning grant study of the gate complex is underway and no firm plans exist yet.

3.19.3 Deployment Time Phasing

The inputs to the deployment analysis for DAY are presented in Table 3-19 and the ASTC systems deployment time phasing is summarized in Figure 3-19. An ASDE can be justified for the ground controller in bad visibility by 1989, but it appears that an ASE cannot be justified for either controller until at least the turn of the century.

3.20 SAN ANTONIO INTERNATIONAL AIRPORT (SAT)

The following summarizes the results of the ASTC deployment analysis at SAT.

3.20.1 Present Facilities and Operations

The present runway configuration at SAT consists of five runways: a set of dual lanes, 12R/30L (8500 feet long) and 12L/30R (3600 feet long) separated by 1000 feet; another set of parallel runways, 3R/21L (7500 feet long) and 3L/21R (2600 feet long) separated by 4000 feet; and runway 17/35 (2400 feet long). Only runways 3R/21L and 12R/30L are used for air carrier operations. These two runways form a "T" at the 30L end of the longer of the two runways. The preferred runway configuration for good and bad visibility conditions during air carrier peak periods is: arrivals and departures on R12R. There are noise abatement restrictions that prevent operations on R3R/21L during night hours and departures from R12R must maintain the runway heading until 3000 feet MSL is reached before turning.

The taxiway system is not adequate to establish a one-way traffic flow pattern at present. However, the flow could be attained by an additional parallel taxiways.

The present gate complex consists of 16 air carrier gates, of which 5 can accommodate jumbo jets. The resulting capacity appears sufficient to accommodate the present traffic and the projected traffic for at least 20 years.

3.20.2 Future Facilities and Operations

The only plans to improve the runways at SAT are to extend runway 3R to 8300 feet and runway 12L to 5000 feet. These improvements will not significantly change the capacity estimates used here. There are other plans to expand the aprons.

The plans to expand the gate complex are uncertain at this time.

TABLE 3-19

DEPLOYMENT ANALYSIS INPUTS: DAY

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
5.0	4.1	0700-2300	19	53 196	64 299	29	40

System Capacities

PERIOD	REPRESENTATIVE[1] PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(24L), S(24R)	108 120	80 86 120	90 115	35 68 115	20	32
FUTURE	- - - - - - S A M	E A S	A B O V E - -	- - - - - -	- - - - - -	- - - - - -	- - -

(1) RUNWAY CONFIGURATION:
S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

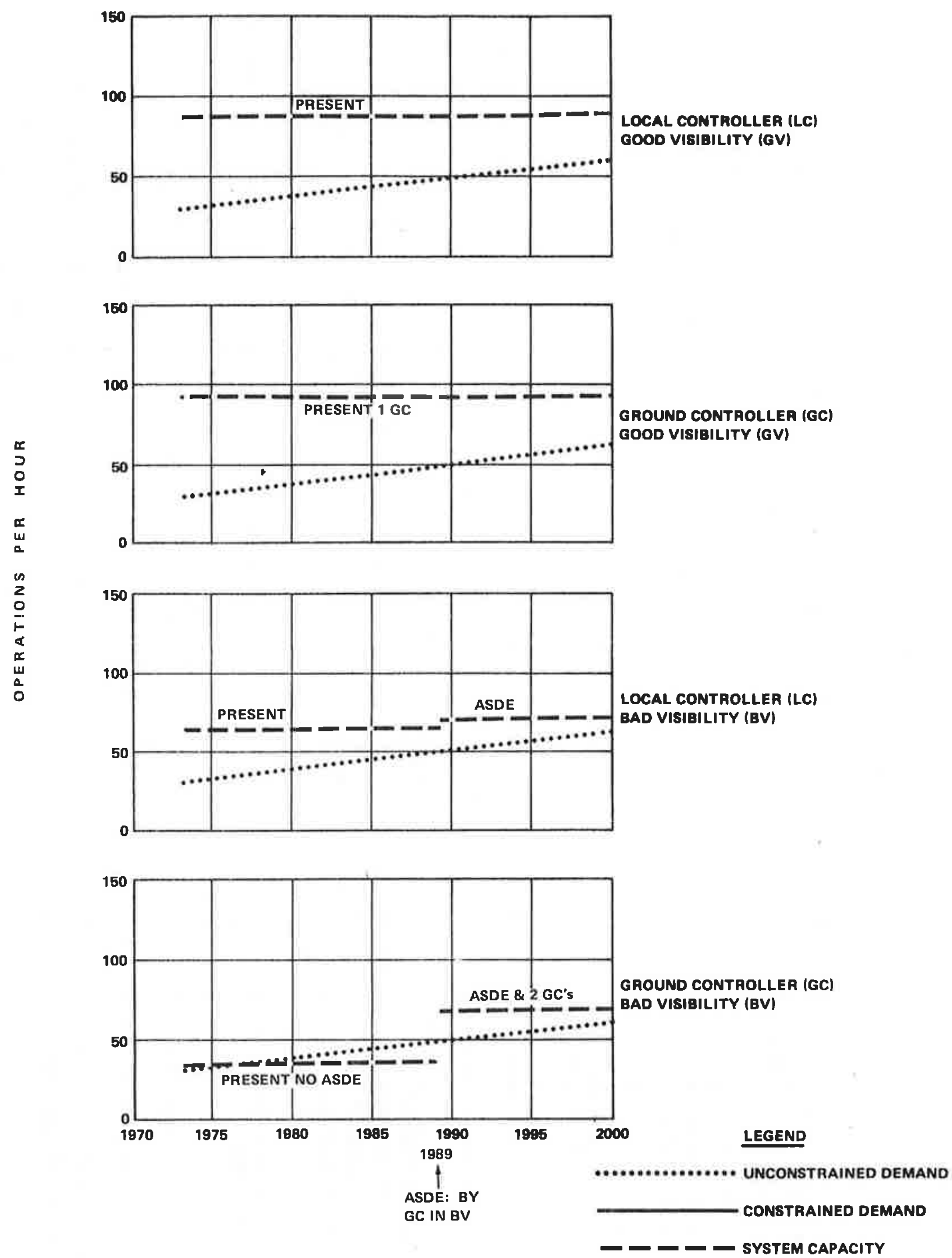

Figure 3-19. Cox Dayton Municipal Airport
ASTC Systems Deployment

TABLE 3-20
DEPLOYMENT ANALYSIS INPUTS: SAT

Weather Conditions and Demand

BAD VISIBILITY (CAT II & IIIA)		BUSY HOURS	1973 PEAK SCHEDULED AIR CARRIER (OPH)	DEMAND ANNUAL OPERATIONS (1000)		DAILY PEAK OPERATIONS PER HOUR	
YEARLY FREQUENCY > THAN 90 MIN. DURATION	AVERAGE DURATION (HOURS)	(TIME OF DAY)		1973 AIR CARRIER TOTAL	1983 AIR CARRIER TOTAL	1973	1983
4.9	2.7	0700-2100	14	51 280	69 333	27	33

System Capacities

PERIOD	REPRESENTATIVE(1) PEAK HOUR RUNWAY CONFIGURATION	CONTROLLER CAPACITY				GATES	
		RWY/LC CAPACITY (OPH)		GC CAPACITY (OPH)		NUMBER	CAPACITY (OPH)
		GV	BV	GV	BV		
		PRESENT ASE	NO ASDE ASDE ASE	PRESENT ASE	NO ASDE ASDE ASE		
1973	S(12R)	54 60	40 43 60	90 115	35 68 115	16	26
FUTURE	-- SAME AS ABOVE --	--	--	--	--	--	--

(1) RUNWAY CONFIGURATION:

S - SINGLE, MIXED
S' - PAIR OR INDEPENDENT SINGLE RUNWAYS, ARRIVALS ON ONE, DEPARTURES ON THE OTHER.
D - DUAL LANE.
D' - DUAL LANE SPACED SO EXITING ARRIVALS DO NOT AFFECT OTHER RUNWAY.
F - FAR-END CROSSING.
N - NEAR-END CROSSING.
M - MID CROSSING.

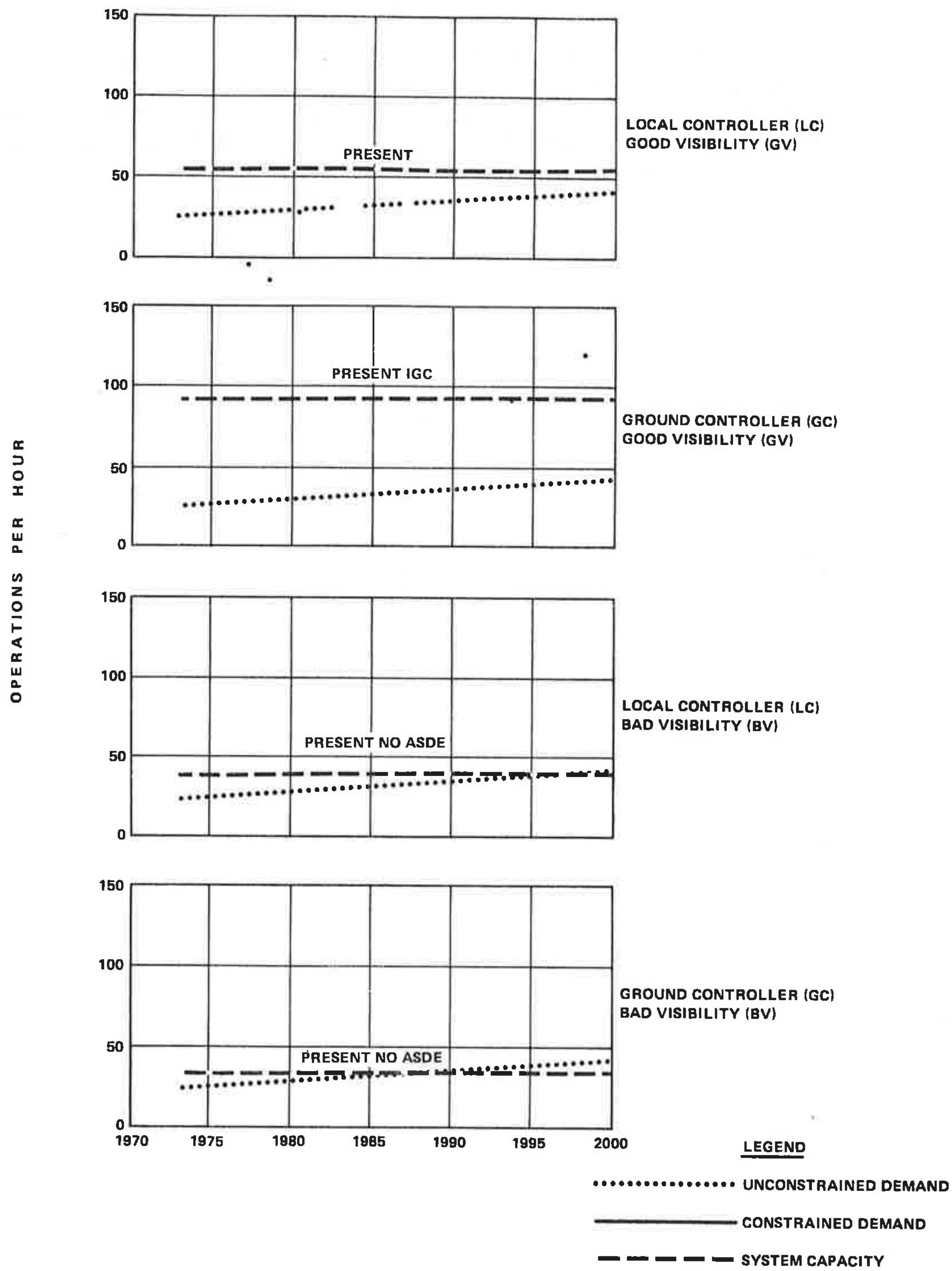

Figure 3-20. San Antonio International Airport ASTC Systems Deployment

3.20.3 Deployment Time Phasing

The inputs to the deployment analysis for SAT are presented in Table 3-20 and the ASTC systems deployment time phasing is summarized in Figure 3-20. It appears that neither an ASDE nor an ASE can be justified for either controller, at least through the end of this century.

4. DEPLOYMENT SUMMARY

A summary of the deployment time phasing charts from Section 3 is presented in Table 4-1. This table is presented merely to show the results of the deployment analysis for the 20 additional airports that are presented in Section 3 of this report. A more meaningful summary of all 39 airports (19 from Reference 1) is presented in Table 4-2. To place the summaries in proper context, the following assumptions are reemphasized:

1. Category II and IIIA operations are assumed to exist at all 39 airports now. Thus, some of the airports which show a current need for ASDE will not actually need an ASDE until the late 1970's. This assumption was made to simplify the computations and is considered valid since new ASDE deployment is not scheduled until the late 1970's (Reference 3).

2. Metering and spacing to provide precisely managed arrival spacing is assumed to be installed at the same time as the Advanced Surveillance Equipment. Thus, those units required for local control alone will not actually be required until the late 1970's. The rationale for this assumption is similar to Item 1 above.

Neither table includes deployment of the Autonomous Intersection Control and Standard Taxiway Routing systems. Although these alternatives were considered, it was determined that they were not required for the following reasons:

a. The ASE provided the greatest payoff of all systems considered and hence was deployed first.

b. Neither the AIC system or STR system provided any improvements to local controller operations.

c. Almost all of the airports become runway limited, and the ASE system is the only candidate system that affects the capacity of the local controller/runway system.

d. Given that the ASE system is deployed, the airports are still runway limited at a lower level than the estimated capacity of ground control.

This latter reason is a major finding of the deployment analyses. Of the 20 airports (from the total of 39 airports) that could justify an ASE system, 15 justified it for the local controller

TABLE 4-1

POTENTIAL ASTC DEPLOYMENTS: EXPANDED SURVEY

	ASDE		ASE	
AIRPORT	DATE	DETERMINING FACTOR	DATE	DETERMINING FACTOR
DFW	1973	GCBV	1995	GCGV,GCBV
DEN	1979	GCBV	1982	LCGV
STL	1973	GCBV	1983	LCGV
IAH	1978	GCBV	>2000	--
MSP	1989	GCBV	1995	LCGV
MSY	1985	GCBV	>2000	--
MEM	1996	GCBV	>2000	--
MCI	1978	GCBV	>2000	--
IND	1988	GCBV	>2000	--
CVG	>2000	--	>2000	--
PDX	1991	GCBV	>2000	--
SAN	1992	GCBV	>2000	--
BUF	>2000	--	>2000	--
MKE	1985	GCBV	>2000	--
CLT	>2000	--	>2000	--
CMH	>2000	--	>2000	--
IAD	1992	GCBV	>2000	--
SDF	>2000	--	>2000	--
DAY	1989	GCBV	>2000	--
SAT	>2000	--	>2000	--

DETERMINING FACTORS

GCGV - Ground Control in Good Visibility
LCGV - Local Control in Good Visibility
GCBV - Ground Control in Bad Visibility
LCBV - Local Control in Bad Visibility

TABLE 4-2

POTENTIAL ASTC DEPLOYMENTS: ALL 39 AIRPORTS

AIRPORT	ASDE		ASE	
	DATE	DETERMINING FACTOR	DATE	DETERMINING FACTOR
ORD	1973*	GCBV	1973	LCGV,GCGV,GCBV
ATL	1973*	GCBV	1975	GCBV
LAX	1973*	GCBV	1976	GCBV
JFK	1973*	GCBV,LCBV	1982	LCGV
LGA	1973	GCBV	1982	LCGV
SFO	1973*	GCBV	1978	LCGV
DFW	1973	GCBV	1995	GCGV,GCBV
MIA	>2000	--	1974	LCGV
DCA	1973	GCBV	1973	LCBV
BOS	1973*	GCBV	1984	LCGV
PIT	1973	GCBV	1978	LCGV
DEN	1979	GCBV	1982	LCGV
STL	1973	GCBV	1983	LCGV
DTW	1973	GCBV	1995	LCGV
EWR	1976*	GCBV	1988	LCGV
PHL	1973	GCBV	1981	LCGV
CLE	1973*	GCBV	1980	LCGV
IAH	1978	GCBV	>2000	--
MSP	1989	GCBV	1995	LCGV
MSY	1985	GCBV	>2000	--
SEA	1973*	GCBV	1983	LCGV
MEM	1996	GCBV	>2000	--
MCI	1978	GCBV	>2000	--
IND	1988	GCBV	>2000	--
CVG	>2000	--	>2000	--
BAL	1983	GCBV	1990	LCGV
PDX	1991*	GCBV	>2000	--
PHX	>2000	--	>2000	--
SAN	1992	GCBV	>2000	--
BUF	>2000	--	>2000	--
MKE	1985	GCBV	>2000	--
CLT	>2000	--	>2000	--
CMH	>2000	--	>2000	--
IAD	1992*	GCBV	>2000	--
SDF	>2000	--	>2000	--
DAY	1989	GCBV	>2000	--
OAK	>2000	--	>2000	--
BDL	1992	GCBV	>2000	--
SAT	>2000	--	>2000	--

*ASDE Currently Installed

DETERMINING FACTORS
- GCGV - Ground Control in Good Visibility
- LCGV - Local Control in Good Visibility
- GCBV - Ground Control in Bad Visibility
- LCBV - Local Control in Bad Visibility

in good visibility conditions, and given the deployment of ASE for the local controller, the ground controller capacity was sufficient to meet any future demand that is constrained by the local controller/runway system. The five airports that could justify an ASE for any of the other controller/visibility combinations earlier than the local controller in good visibility were ORD, ATL, LAX, DFW and DCA.

APPENDIX A

REFERENCES

1. Federal Aviation Administration, Airport Surface Traffic Control Systems Deployment Analysis, Final Report, FAA-RD-74-6, Washington, D. C., January 1974.

2. Federal Aviation Administration, A Preliminary Requirements Analysis for Airport Surface Traffic Control, Interim Report, FAA-RD-73-6, Washington, D. C., January 1973.

3. Federal Aviation Administration, Engineering and Development Program Plan - Airport Surface Traffic Control, FAA-ED-08-1, Washington, D. C., July 1972.

4. Civil Aeronautics Board, Congressional Airport Congestion Study, Washington, D. C., 1971.

5. Federal Aviation Administration, Operations Reservations for High-Density Traffic Airports, AC-90-43, Washington, D. C., 25 March 1969.

6. McGraw-Hill, Inc., Aviation Week and Space Technology, New York, New York.

7. Federal Aviation Administration, Profiles of Scheduled Air Carrier Airport Operations, Top 100 U. S. Airports, Friday, November 3, 1972, Washington, D. C., January 1973.

8. Federal Aviation Administration, Terminal Area Forecast 1973-1983, Washington, D. C.

9. Federal Aviation Administration, FAA Air Traffic Activity, CY 71, Washington, D. C., February 1972.

10. Federal Aviation Administration, Climatological Summaries Visibilities Below 1/2 Mile and Ceiling Below 200 Feet, SRDS Report Number 69-22, Washington, D. C., June 1969.

11. Federal Aviation Administration, Ceiling - Visibility Climatological Study and Systems Enhancement Factors, DOT-FA73WAI-330, Ashville, N. C., June 1973.

12. Transportation Systems Center, Department of Transportation, JFK Airport Ground Control Recommendations, DOT-TSC-FAA-72-14, Cambridge, Massachusetts, November 1972.

13. Department of Transportation, Office of Policy Review, Aviation Cost Allocation Study, FAA Airport and Airway System Cost Elements, Working Paper, February 1972.

14. Federal Aviation Administration, Cost Estimates for National Airspace System Facilities, Project No. 197-641-04R, Washington, D. C., August 1968.

APPENDIX B

LIST OF ABBREVIATIONS AND ACRONYMS

AC	Air Carrier
AIC	Autonomous Intersection Controller
ARO	Airport Reservation Office
ARTS	Automated Radar Terminal System
ASDE	Airport Surface Detection Equipment
ASE	Advanced Surveillance Equipment
ASR	Airport Surveillance Radar
ASTC	Airport Surface Traffic Control
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATL	Atlanta International Airport
BAL	Friendship International Airport
BDL	Bradley International Airport
BOS	Boston-Logan International Airport
BUF	Greater Buffalo International Airport
BV	Bad Visibility
C_D	Yearly aircraft delay costs
C_m	Cost per minute of aircraft delay
C_s	Yearly system cost
CAT	Category of weather
CLE	Cleveland-Hopkins International Airport
CLT	Douglas Municipal Airport, Charlotte, N. C.
CMH	Port Columbus International Airport, Columbus, Ohio
CVG	Greater Cincinnati Airport
D	Minutes of aircraft delay
DAL	Dallas Love Field
DAY	Cox Dayton Municipal Airport
DCA	Washington National Airport
DEN	Stapleton International Airport, Denver, Colorado
DFW	Dallas-Fort Worth Airport
DTW	Detroit-Metropolitan Wayne County Airport
EWR	Newark International Airport
FAA	Federal Aviation Administration
FY	Fiscal Year
GA	General Aviation
GC	Ground Controller or Ground Control
GV	Good visibility

IAD	Washington-Dulles International Airport
IAH	Houston Intercontinental Airport
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IND	Indianapolis Municipal Airport
JFK	J. F. Kennedy International Airport
LAX	Los Angeles International Airport
LC	Local Controller or Local Control
LGA	La Guardia Airport
MCI	Kansas City International Airport
MEM	Memphis International Airport
MIA	Miami International Airport
MKC	Kansas City Municipal Airport
MKE	General Mitchell Field, Milwaukee, Wisc.
MSP	Minneapolis-St. Paul International Airport
MSY	New Orleans International Airport
N	Hourly demand rate in oph
OAK	Metropolitan Oakland International Airport
oph	Operations per hour
ORD	Chicago O'Hare International Airport
P	Performance capacity in operations per hour
PDX	Portland International Airport
PHL	Philadelphia International Airport
PHX	Pheonix Sky Harbor International Airport
PIT	Greater Pittsburgh International Airport
PPI	Plan Position Indicator
RWY	Runway
R17L	Runway 17 left
SAN	San Diego International-Lindbergh Field
SAT	San Antonio International Airport
SDF	Standiford Field, Louisville, Ky
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport
STL	Lambert-St. Louis International Airport
STR	Standard Taxiway Routing
TCA	Terminal Control Area
VFR	Visual Flight Rules
VHF	Very High Frequency
Z	Number of busy hours for an airport

APPENDIX C

SAMPLE CALCULATIONS FOR ASTC DEPLOYMENT ANALYSIS

C.1 PURPOSE

This appendix presents sample calculations used to determine the ASTC deployment time phasing chart for the Dallas-Fort Worth Airport. The chart is presented in Figure 3-1 in the text using the basic inputs from Table 3-1, also in the main body of the report.

C.2 UNCONSTRAINED DEMAND

At an airport, the peak operations per hour demand, d, is equal to the scheduled AC (air carrier) peak operations per hour plus an estimate of GA (general aviation) aircraft. The d value in this report is considered to be identical under both good and bad visibility conditions. The air carrier scheduled peak operations per hour for the year 1973, reference 7, are shown on Figure C-1 along with the remaining scheduled hourly operations ranked in decreasing order of magnitude. In order to project the hourly operations, these are assumed to grow in a linear fashion and the rate of growth is directly proportional to the annual air carrier operations. Thus, repeating the data from reference 8, the annual air carrier operations are: 293,000 operations for 1973 and 422,000 operations for 1983.

Hence, for DFW, the air carrier operations per hour for any year are:

$$\phi_{AC} = \phi_{73}\ [293000 + (422000 - 293000)\ T/10]/293000 \qquad \text{(C-1)}$$

where: ϕ_{73} = Hourly operations rate in 1973,

T = Number of years after 1973.

In a similar manner, the total peak hourly operations including the estimated 20% general aviation are obtained from the total annual operations also given in reference 8. The total annual operations are found in reference 8 to be: 419,000 annual operations in 1973 (Dallas-Love Field), and 555,000 annual operations in 1983 (projected for DFW).

The differences between the above figures and the corresponding yearly air carrier operations provide the following annual general aviation operations: 126,000 = 419,000 - 293,000 in 1973 and 133,000 = 555,000 - 422,000 in 1983.

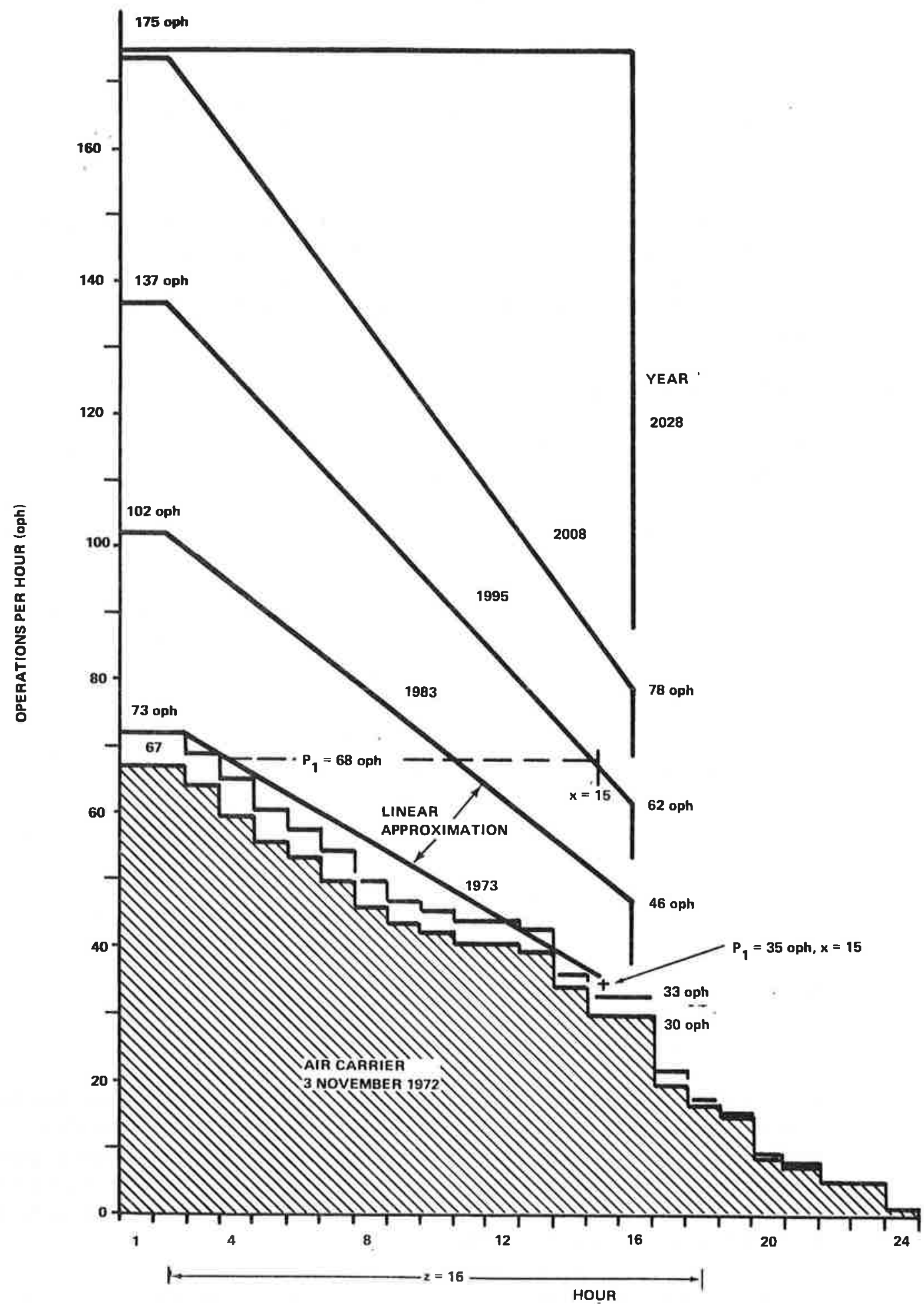

Figure C-1. Dallas-Fort Worth Operations per Hour Ranked by Order of Magnitude Covering a 24-Hour Day

Considering that 20% of the above annual general aviation totals require service and capabilities similar to air carriers at an airport, these annual populations become: 318,200 = 293,000 + 0.2 (126,000) in 1973 and 448,600 = 422,000 + 0.2 (133,000) in 1983.

The hourly operations rates grow, if unconstrained, in accordance with:

$$\phi = \phi_{73} \, [318200 + (448600 - 318200)\, T/10]/293000 \qquad \text{(C-2)}$$

$$= \phi_{73} \, [3182 + 130.4T]/2930.$$

Thus in 1973 the peak hourly operations, h_1, are from equation (C-2).

$$h_1 = 67\ [3182/29302] = 73 \text{ oph},$$

and in 1983:

$$h_1 = 67\ [3182 + 130.4(10)]/2930$$

$$= 102 \text{ oph}.$$

The hourly operations on Figure C-1 appear to be linearly decreasing for the first 16 hours and then there is a step jump to lower values during the early morning hours. Included in these 16 hours are those from 0700 through 2300. Hence Z = 16 hours in Equation (2-7) of the report and from equation (C-2) with ϕ_{73} = 30 oph in the 16th hour, the values of h_2 during these hours are:

$$h_2 = 33 \text{ oph in 1973},$$

$$= 46 \text{ oph in 1983}.$$

C.3 LOCAL CONTROLLER IN GOOD VISIBILITY

The local control position capacities in good visibility as given in Table 3-1 in the report are

P = 147 oph in 1973 and no ASE,

= 163 oph in 1973 with ASE,

= 174 oph with additional runways and no ASE,

= 193 oph with additional runways and ASE.

From section 2 in the report, the peak hourly demand d will be constrained when it reaches the value of

$$d = P/1.1. \qquad \text{(C-3)}$$

Using equation (C-2) to solve for the number of years T when d = 147/1.1 = 133 oph, it is found that in T = 20 years or in 1993 the additional runway capacity will be needed thereby raising the P value to 174 oph (still without ASE). The year when ASE will be needed by the local control position is when d = 174/1.1 = 158 oph which is T = 29 years from 1973 or the year 2002. With ASE and the additional runways, the ultimate hourly peak demand will reach d = 193/1.1 = 175 oph in the year 2008. Then the hourly operations will fill in the non-peak hours on Figure C-1 and the number of peaks will grow from n_o = 2 peaks to 16 peaks in accordance with equation (2-5) in the report. The 16 peak values will be reached using equation (2-5) when:

$$T_s = \frac{365ZP - 0.99\ a_2}{0.99\ a_1} \qquad \text{(2-5)}$$

= 20 years or the year 2028.

In the above:

Z = 16 hours

P = 175 oph

a_1 = 13,040 operations per year, unconstrained growth rate.

a_2 = 318,200 + 13,040 (35) = 774,600 annual operations in year 2008.

The criterion used for picking 2002 as the year when ASE is needed by the local control position is based on equation (C-3) being satisfied in that year. However, equation (2-3) in the report must also be satisfied or the values of the peaks will grow from n_o = 2 until n equals a value when the conditions of equation (2-3) are first met and the ASE is justified. Rewriting equation (2-3) for convenience:

$$nd \geq C_s/(100C_m), \qquad \text{(2-3)}$$

where:

$n = 2$ peaks,

$d = 158$ oph,

$C_s = \$181,060 + \$4,030\ r$

$= \$229,420$ if $r = 12$ receivers for Dallas - Ft. Worth,

$C_m = \$10/\text{minute}$ = Average cost of delay of an aircraft,

the inequality is satisfied, being:

$316 > 229.$

Hence the peak hourly loads will justify an ASE in the year 2002 for the local control position.

C.4 GROUND CONTROLLER IN GOOD VISIBILITY

The ground control position has the following capacities, see Table 3-1:

$P = 90$ oph, one ground controller and no ASE,

$= 138$ oph, two ground controllers and no ASE,

$= 175$ oph, two ground controllers with ASE.

Using the values of P above in equation (C-3) and solving for the years with equation (C-2) the following results are obtained:

one ground controller - good until 1980,

two ground controllers - good until 1995, and

two ground controllers plus ASE needed after 1995.

A check on satisfying the inequality of equation (2-3) results in:

$2(138) > \$229,420/100 \quad (\$10)$

$276 > 229.$

This indicates the ASE system can be justified in 1995 under good visibility conditions for the ground control position. This precedes the year for the local control position,- 2002.

C.5 BAD VISIBILITY PERFORMANCE

Under bad visibility conditions, the questions become: (1) when will ASDE be needed, and (2) can ASE be justified as an ASDE replacement. The ground control position has such a low performance or capacity without ASDE, $P_1 = 35$ oph, that it, not the local control position, governs when ASDE is needed. The equation in the report for determining the costs of the bad visibility delays is repeated below:

$$C_D = 30\ (\$10)t^2 f\frac{x}{Z}(N_1-P_1) \left[\frac{N_1-P_1}{P_2-N_2} + 1\right] \qquad (2\text{-}7)$$

In the above equation for DFW from Table 3-1:

$f = 1.9$

$t = 2.2$

$Z = 16$

$P_1 = 35$ oph, no ASDE, bad visibility

$P_2 = 90$ oph, one controller, good visibility.

A first cut at finding the value of C_D which will satisfy the following:

$$C_D \geq C_S = \$82{,}000 \text{ cost per year for an ASDE} \qquad (C\text{-}4)$$

is made by determining N_1, N_2 and x for 1973. The value of $x = 15$ is obtained from Figure C-1 where the $P_1 = 35$ oph intersects the line connecting $h_1 = 73$ oph and $h_2 = 33$ oph.

The 1973 N_1 is found from the relationship:

$$N_1 = P_1 + (h_1 - P_1)\ \ (x+n)/2x \qquad (C\text{-}5)$$

$$= 35 + (73-35)\ (15+2)/2(15)$$

$$= 57 \text{ oph.}$$

The 1973 N_2 is found as follows:

N_2' = Average bad visibility demand following the N_1 load of t hours duration.

$$= h_2 + (h_1 - h_2)\ \ (Z+n)/2Z \qquad (C\text{-}6)$$

$$= 33 + (73-33)\ (16+2)/2(16)$$

$$= 56 \text{ oph.}$$

The good visibility value N_2 is found from:

$$N_2 = N_2' \; (\phi_{GV}/\phi_{BV}) \qquad \text{(C-7)}$$

where:

ϕ_{GV} = Peak operations per hour in good visibility, and

ϕ_{BV} = Peak operations per hour in bad visibility.

However, $\phi_{GV} = \phi_{BV}$ for this analysis which results in N_2 = 56 oph.

Substituting the above values in (2-7) gives C_D = $93,715.

Putting C_D in equation (C-4) shows that the inequality exists in 1973. Hence, the ASDE is justified now by the ground controller for CAT II/IIIA operations.

A first try on finding the year when ASE is needed in bad visibility is made by evaluating equation (2-7) for the same year ASE is first needed in good visibility, 1995. The P_1 value for two ground controllers with ASDE is 68 oph, Table 3-1, which is less than the local-controller-plus-ASDE capacity of P_1 = 137 oph when the runways have been added.

The values of N_1 and N_2, equations (C-5, 6, and 7), are obtained using 1995 values shown on Figure C-1 of:

h_1 = 137 oph

h_2 = 62 oph

n = 2

x = 15

z = 16

P_1 = 68 for two ground controllers and ASDE

P_2 = 138

Then:

N_1 = 107 oph,

N_2 = 104 oph, and

C_D = $216,565 which is the cost of delays in 1995 with ASDE.

The ASE value of P_1 = 175 oph can reduce the C_D to zero, and C_s = $229,420 for the annual operation of an ASE almost equals C_D. Hence ASE can be justified in 1995 for the ground controller in bad visibility as well as in good visibility.

C.6 CAT II/IIIA WEATHER ESTIMATING

There are 39 airports which have been examined in this report and reference 1. The weather data in the detailed format of reference 10 covers all but four of the 39 airports. The four airports are MEM (Memphis International Airport), SAT (San Antonio International Airport), SAN (San Diego International-Lindbergh Field), CLT (Douglas Airport, Charlotte, N. C.).

These airports are among the 226 airports/locales in reference 11 in which the breakdown of the weather data is not as extensive as in reference 10.

The data in reference 11 lists the percentages of the "observations" over a number of years which were CAT II and III during the daily periods of 0700 through 1300 hours, 1400 through 2100, and 2200 through 0600. (An "observation" in reference 11 is synonymous with one-hour). To convert these values to values similar to those extracted from reference 10, data from the latter were used to obtain linear regression lines on the 41 airports in reference 10. The linear regression lines represent best average fits so that the CAT II weather observations in reference 11 can be converted to the portions covering 91 minutes or more or 361 minutes or more. Similarly the CAT III weather can be transformed to CAT IIIA weather.

As an example the CAT III MEM weather given in reference 11 for the period, p, of 0700 through 1300 hours of the day, is listed as 0.2% of the 43,465 observations evaluated in that seven hour period. Since there are a total of 149,027 observations, the overall percentage of CAT III weather at MEM is found by using the following equation:

$$t_{mp} = A_{mp} \quad T_{np} \qquad \text{(C-8)}$$

where subscript p refers to period of day, i.e.,

p = 1 for period 0700 through 1300 hours

2 for period 1400 through 2100 hours

3 for period 2200 through 0600 hours.

Also: t_{mp} = Percent of total observations in category m for period of day p,

where: m = 2 indicates t covers CAT II weather lasting longer than 91 minutes if p = 1, 2, and lasting longer than 361 minutes if p = 3.

= 3A indicates t covers category CAT IIIA weather lasting longer than 91 minutes if p = 1, 2 and lasting longer than 361 minutes if p = 3.

The value: T_{np} = Percent of total observations in category n for period of day p,

where: n = 2 if M = 2 and indicates T is for all CAT II weather in period p,

= 3 if m = 3A and indicates T is for all CAT III weather in period p, and p is defined as for m above.

The constant A_{mp} = linear regression line slope for the period of day p and category m weather.

For MEM with the period P = 1, i.e., 0700 through 1300, and:

$T_{np} = T_{31}$ for CAT III weather.

$T_{31} = 0.2\% \ (43465/149027)$

$= 0.0583\%.$

$A_{mp} = A_{3A1} = 0.287$ from Table C-1.

Then in equation (C-7)

$T_{3A1} = 0.287 \ (0.0583\%)$

$= 0.0168\%.$

Therefore, over a ten year period with a total of 87,672 hours, there will be 0.0168% (87,672 hours) = 14.72 hours of CAT IIIA weather during the 0700 through 1300 hours of the day with a duration of 91 minutes or more.

An approach similar to the above with frequencies of occurrence from reference 10, plotted against times in percentage, yielded regression lines with the generalization that:

$$t_{mp} = B_{mp} \; f_{mp} \qquad \text{(C-9)}$$

In the above the subscripts m and p have the same significance as in equation (C-7). B_{mp} is the regression line coefficient relating t_{mp} to the frequency of occurrence in a 10 year period. Thus for the MEM example:

$t_{mp} = t_{3A1} = 0.0168\%$

$B_{mp} = B_{3A1} = 0.00360$

$f_{mp} = f_{3A1}$ = Frequency of CAT IIIA weather lasting longer than 91 minutes during 0700-1300 hours of the day in a 10 year time span.

= 4.67 from equation (C-7).

The values of durations and frequencies during the three daily periods p can be evaluated using the values of A_{mp} and B_{mp} on Table C-1.

TABLE C-1

LINEAR REGRESSION LINE CONSTANTS FOR CAT II/IIIA WEATHER

		A_{mp} VALUES		B_{mp} VALUES	
	TIME PERIOD	CAT II m = 2	CAT IIIA m = 3A	CAT II m = 2	CAT IIIA m = 3A
1	0700-1300 hours, 91 minutes to all	0.347	0.287	0.00332	0.00360
2	1400-2100 hours, 91 minutes to all	0.517	0.368	0.00357	0.00416
3	2200-0600 hours, 361 minutes to all	0.059	0.057	0.01046	0.00912

APPENDIX D

REPORT OF INVENTIONS

A diligent review of the work performed under this contract has revealed no new innovations, discovery, improvement or invention.