REPORT NO. DOT-TSC-FAA-72-8

EVALUATION OF THE FAA ADVANCED FLOW CONTROL PROCEDURES

J.F.BELLANTONI,J.R.COONAN,
M.F.MEDEIROS
TRANSPORTATION SYSTEMS CENTER
55 BROADWAY
CAMBRIDGE, MA. 02142

transpo 72
U.S. International Transportation Exposition
Dulles International Airport
Washington, D.C.
May 27-June 4, 1972

JANUARY 1972
TECHNICAL REPORT

Prepared for
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D. C. 20591

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-TSC-FAA-72-8		

4. Title and Subtitle	5. Report Date
EVALUATION OF THE FAA ADVANCED FLOW CONTROL PROCEDURES	January 1972
	6. Performing Organization Code
7. Author(s) J. F. Bellantoni, J. R. Coonan, M.F. Medeiros	8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Transportation Transportation Systems Center 55 Broadway Cambridge, MA 02142	10. Work Unit No. R-2137 11. Contract or Grant No. FA206
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Washington, D. C. 20591	13. Type of Report and Period Covered Technical Report FY71-72 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report is an evaluation of the present FAA Advanced Flow Control Procedures (AFCP), based on data gathered from its implementation on February 5, 1971 and on a fast-time digital simulation of traffic feeding into the NY airports on that day. The report discusses the effectiveness of AFCP in theory, in the February 5 case study, and as modelled in the simulation. Recommendations are made 1) to retain the concept, 2) to modify the procedures, 3) to modify the computer program, and 4) to conduct further research.

17. Key Words	18. Distribution Statement
Flow Control, Advanced Flow Control Procedures, Air Traffic Control, Central Flow Control Facility	Availability is Unlimited. Document may be Released To the National Technical Information Service, Springfield, Virginia 22151, for Sale to the Public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	215	

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LIST OF COMMON ACRONYMS & ABBREVIATIONS

A/C	Air Carrier
AFCP	Advanced Flow Control Procedures
AFCR	Advanced Flow Control Restrictions
ARO	Airport Reservations Office
ARTCC	Air Route Traffic Control Center
ATA	Assigned Time of Arrival
ATC	Air Traffic Control
ATD	Assigned Time of Departure
CATER	Collection and Analysis of Terminal Records
$(CF)^2$	CFCF
CFCF	Central Flow Control Facility
CIFRR	Common IFR Room
CONUS	Continental United States
DCA	Washington, D. C. (Airport)
DLY	Delay
ETE	Estimated Time Enroute
EWR	Newark (Airport)
FCFS	First Come First Served
FL	Flight Level
FSS	Flight Service Station
FWS	Federal Weather Service
G/A	General Aviation
GMT	Greenwich Mean Time
HDT	High Density Terminal
ID	Identification Code (of a flight)
IFR	Instrument Flight Rules
ILS	Instrument Landing System
JFK	John F. Kennedy (Airport)
LGA	LaGuardia (Airport)
MGD	Maximum Ground Delay
OAG	Official Airline Guide
PHL	Philadelphia (Airport)
PTA	Planned Time of Arrival
PTD	Planned Time of Departure
RSTNS	Restrictions
R/W	Runway
TA	Time of Arrival
TA*	Time of Arrival, less arrival delays
TATA	Tentative Assigned Time of Arrival
TACAN	Tactical Air Navigation (UHF Navigational Aid giving omnidirectional course information)
TD	Time of Departure
TENR*	TA* minus TD
VAST	Versatile Air Traffic Simulation Technique
VFR	Visual Flight Rules
VOR	Very High Frequency Omnidirectional Range (VHF Navigational Aid giving omnidirectional course information)

LIST OF COMMON ACRONYMS & ABBREVIATIONS (CONT.)

VORTAC	Radio Navigation Station Combining VOR and TACAN, q.v.
Z (prefix	ARTCC
Z (suffix)	GMT
ZAB	Albuquerque Air Traffic Control Center
ZAU	Chicago Air Traffic Control Center
ZBW	Boston Air Traffic Control Center
ZDC	Washington, D.C. Air Traffic Control Center
ZDV	Denver Air Traffic Control Center
ZFW	Fort Worth Air Traffic Control Center
ZGT	Great Falls Air Traffic Control Center
ZHU	Houston Air Traffic Control Center
ZID	Indianapolis Air Traffic Control Center
ZJX	Jacksonville Air Traffic Control Center
ZKC	Kansas City Air Traffic Control Center
ZLA	Los Angeles Air Traffic Control Center
ZLC	Salt Lake City Air Traffic Control Center
ZMA	Miami Air Traffic Control Center
ZME	Memphis Air Traffic Control Center
ZMP	Minneapolis-St. Paul Air Traffic Control Center
ZNY	New York Air Traffic Control Center
ZOA	Oakland Air Traffic Control Center
ZOB	Cleveland Air Traffic Control Center
ZSE	Seattle Air Traffic Control Center
ZTL	Atlanta Air Traffic Control Center
ZUL	Montreal Air Traffic Control Center
ZYZ	Toronto Air Traffic Control Center
ZBW/O	Boston Air Traffic Control Center/O versus
ZDC/O	Washington, D.C. Air Traffic Control Center/O versus
ZNY/O	New York Air Traffic Control Center/O versus

INTRODUCTION

PURPOSE

This report is an evaluation of the present FAA Advanced Flow Control Procedures (AFCP) under actual and simulated air traffic conditions. The primary purposes of the evaluation are:

- To determine the effectiveness of the procedures both in theory and in application.
- To determine the adequacy of the data used in the procedures.
- To investigate modifications of the procedures.

BACKGROUND

Advanced Flow Control Procedures are designed specifically for the New York terminal area as an initial attempt to promote an orderly flow of traffic into a high density area. The procedures are implemented when excessive air delays are anticipated due to unusually high demand or low capacity. The initial manual system was introduced in December of 1968. By December of 1969, it had been converted into an automated system. The automated system, which is still in operation, is based on a computer program written by MITRE Corp. under FAA direction and run on the Kansas City ARTCC 9020 computer. During 1970, it was implemented ten times*, but the results have never been evaluated. Indeed, no data are available on which to base an evaluation. On 5 February 1971, the New York ARTCC implemented AFCP. The FAA Systems Research and Development Directorate (SRDS), in conjunction with the Office of Systems Engineering Management (OSEM) and the Air Traffic Service (ATS), decided that this would be an appropriate time to evaluate the effectiveness of the procedures and requested that such a task be carried out by the Transportation Systems Center (TSC) under the auspices of PPA FA-17. The work here reported was done by TSC from February to September 1971 with the assistance of numerous people in SRDS, NAFEC, ATS and OSEM. The approach taken in the evaluation was to divide the problem into four subtasks:

1. An examination of pertinent FAA orders, MITRE documents, computer program, and discussions with operating personnel to determine how AFCP works, in theory and in practice;

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* Jan. 18, Jan. 23, Feb. 10, Feb. 15, March 2, March 4, March 20, June 5, June 11, July 10, as given in the NYARTCC Log.

2. The establishment of measures of effectiveness;
3. Collection and analyses of flight strips and ARTCC logs to form a case study of AFCP on February 5, 1971;
4. Computer simulation of the high altitude traffic feeding New York so as to determine the sensitivity of the effectiveness measures to changes in data and control procedure, and under more general conditions than represented by the February 5 data.

ORGANIZATION OF REPORT

The next four sections of the report correspond to the four subtasks just described. The final section of the report lists the findings from the subtasks, interprets them, and presents recommendations.

ANALYSIS OF AFCP

A distinction must be made at the outset among the various operational forms of AFCP. These are:

1. The original FAA Orders, dating from October 1968;
2. The manual implementation of those orders, employed from November 1968 through December 1969;
3. The AFCP computer program, employed from January 1970 to the present;
4. The procedures employed by Air Traffic Control in conjunction with the computer program.

THE FAA ORDERS

The AFCP are governed by: FAA/Order 7230.9A, title Advanced Flow Control Procedures, dated 12/19/68; FAA/Order 7230.10, title, Advanced Flow Control Implementing Procedures, dated 10/17/68; FAA/Order 7230.11, title, Advanced Flow Control Procedures for International Flights, dated 12/19/68; FAA Advisory Circular 90-43A, title, Operations Reservations for High Density Traffic Airports, dated 12/23/69. These orders are reproduced for reference in Appendix A.

Purpose

The purposes of AFCP, as set out by the FAA Orders, must be taken into consideration in an evaluation of their effectiveness. The following is given in substantially the same words by both 7230.10, paragraph 6 and by 7230.9A, paragraph 7:

"PROCEDURAL CONCEPT. AFCPs are designed to:

a. Hold aircraft on ground at departure points to absorb delays in excess of one hour.
b. Distribute delays equitably among all users.
c. Eliminate holding of traffic destined for EWR, LGA, or JFK in other than New York Center's airspace. (International traffic in Boston or Washington Center's area is excepted.)
d. Limit holding in New York Center's area to one hour (or less, provided sufficient demand can be maintained on the ATC system to preclude unnecessary gaps in the arrival sequence)."

A more general statement, that introduces the intent of predicting arrival delays, is given in 7230,9A, paragraph 6:

> "AFCPs have been developed to provide the ATC system and its users with some reasonable degree of arrival delay prediction in high density terminal areas. The procedures are to be implemented in advance to become effective during peak traffic hours in designated terminals."

Procedures

The method by which the stated purposes are to be achieved is also outlined in the FAA Orders in terms of duties and procedures for the flow controller at NYARTCC, for all the ARTC Centers, for the Coordination Centers (see 7230, 0A, 12g), and for the Flight Service Stations. The essential steps are summarized below:

1. Estimate the hourly landing capacity of each of the N.Y. airports for the period 8:00 a.m. through 12:00 midnight. This estimate is to be made before 8:00 a.m. based on weather, runway conditions, and other pertinent conditions.
2. Estimate demand for the same period, based on schedules, statistical history, flight plans, and other data.
3. Determine the anticipated arrival delays, i.e., delays in waiting to land upon arrival at the N.Y. Center.
4. Initiate AFCP only for periods when arrivals delays are anticipated to reach one hour.
5. Issue allocations to the affected centers via service B, for each hour and each airport.
6. Compute Assigned Time of Arrival (ATA) and Assigned Time of Departure (ATD) for each aircraft affected by AFCP. The ATA and ATD supersede the Planned Time of Arrival (PTA) and the Planned Time of Departure (PTD).
7. Adjust the allocations among the centers, via the coordination centers, as required by excess ground delays, unexpected demand, takeoff delays, etc.

Method of Determining Allocations and ATAs

The exact method of determining the center allocations, step (5), and the ATAs, step (6), are crucial to the procedures and warrant further discussion. There is to be "A chart depicting the hourly ratio of demand rate to acceptance rate and used by the implementing flow controller as a basis for allocation of release quotas to feeding centers." (7230.10). This wording seems to suggest that a center would be allocated arrivals in any AFCP hour equal to its demand times the ratio of runway capacity to total demand for that hour. The order, however, gives no specific rules for allotting arrivals, leaving to the New York flow controller the actual construction of the allocation charts.

The ATAs, step (6), are calculated by the receiving centers based on the allocation they receive from the New York flow controller. The method of obtaining the ATAs is covered in 7230.9A (8.d. (2) and 8.d. (3)), which state:

"(2) The PTA will determine the order of release for departures, regardless of the PTD. If PTA's are the same, then use PTD's to determine the precedence of departure within each group or hour (resolve identical flights equitably).
(a) Compute PTA by adding estimated time en route (ETE) to PTD.
(b) Group and sequence flights by their PTA for each hour."

"(3) Assign ATA's after referring to AFCR's for hourly quotas. (Assign times of arrival so that the flight will arrive at destination at least 15 minutes after the beginning of the assigned arrival hour.). The ATA will be the same as the PTA for those aircraft within the hourly quotas who have PTA's beyond 15 minutes after the hour."

The hourly quotas referred to* are those precalculated by the New York flow controller in step (5) above. It seems clear that flights in excess of the hourly allotment are to be assigned to subsequent hours in order of their PTAs. Moreover, no arrivals are to be assigned in the first 15 minutes of an hour.

The preceding discussion brings out some questions about the allocations and ATAs of importance to the working of AFCP and to this study.

- <u>How are the ATAs distributed within the assigned arrival hour, beyond the first 15 minutes</u>?

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* The term quota in this context refers to the number arrival aircraft allocated to the centers under AFCP. It should not be confused with the ARO quotas for the New York Airports.

A commonly accepted*answer to this question is that ATAs are to be grouped at 15 minutes after the hour, unless the PTA is beyond 15 minutes after the hour. The rules regarding the sequencing of flights within an hour, laid out in 7230,9A, 8.d.(2) above are aimed more at ordering the ATAs (i.e., who precedes whom) than are spacing them out in time.

Thus, no guidelines are given for distributing the ATAs within the arrival hour. Further, section 8.d(7) of the order states that adding 30 minutes to the ATD (and hence to the ATA) will, "insure that the aircraft reaches the destination pattern within the originally computed ATA hour." This tends to reinforce the belief that assignments at the quarter hour are intended. It will be noted below that the computer program does distribute the ATAs within the arrival hour.

- Why are no arrivals assigned to the first 15 minutes of every AFCP hour?

The second question, that of the purpose of the "15 minute rule", was investigated through discussions with ATC personnel. From these discussions, it was concluded that the major reasons for the rule are:

1. To allow for late arrivals from the previous hour.
2. To prevent flights that have departed 15 minutes early, as allowed by 7230,9A, from interfering with the previous hour's traffic.

The 15 minute rule is clearly stated in the FAA Orders; the aspect of interest to the present evaluation is its effectiveness in practice.

- Are the ATAs to be such as to produce a one hour air delay at New York?

This third question appears to be unresolved by the orders. The stated intent of the orders and a common understanding among AT and SRDS personnel, brought out in discussions with TSC, is that flights under AFCP would experience a one hour delay in the air over New York. This understanding is reinforced by the PROCEDURAL CONCEPT (a) quoted above. Nevertheless, the method given for assigning arrival times makes no reference to a one hour delay upon arrival. In fact, the example given in Appendix 3 of 7230.9A seems to suggest that the entire delay is taken on the ground. This ambivalence of the original 1968 orders was fully exploited by subsequent events: it was discovered in the present study that the manual procedure of 1969 was designed to

*By flow controllers interviewed during the study.

maintain an hour's delay over New York, while the present computer version calculates ATAs for no delay over New York but issues allocations for no specific delay over New York. These two versions of AFCP will be described next.

THE MANUAL AFCP

The major interest here is the method of establishing the hourly allocations for the centers. The manual procedures are similar in other respects to the FAA Orders and to the computerized procedures.

The accompanying tables give a sample manual calculation of the allocations for Thursday, May 15, 1969. Table 1 is a demand chart for LGA, using data from Sunday, May 11 through Saturday, May 17, 1969. The figures are based on air carrier schedules plus 12% general aviation. The 12% was derived from 30 days of traffic from LGA, JFK, and EWR from April 21 through May 21, 1969.

Table 2 is used to determine if, and when, AFCP are to be applied. It is a Flow Rate Chart for an acceptance rate of 24/hour, using the Thursday demand from Table 1. The number of aircraft left over from previous hours is entered in column 2, and subtracted from the acceptance rate of column 3. The difference (which is entered into column 5 if positive, and into column 4 if negative) is then subtracted from the new demand for that hour (column 6) and that difference is entered into column 7, and also into column 2 for the next hour. Thus, column 7 shows the number of aircraft that will be waiting to land in New York at the end of the hour, if no action is taken. When that number exceeds the acceptance rate of 24, a one-hour delay to land can be expected, and AFCP are initiated. When this occurs, as shown in Table 2 at 2300 GMT, some of the 26 delayed aircraft of column 7 are held on the ground (column 9) and the remainder are allocated to hold in the air over New York (column 8).

Once AFCP are initiated, the more detailed allocations of Table 3 are required. This table shows the calculation for the 21 Continental United States (CONUS) centers, plus Montreal, Toronto and the three centers of zone IV that handle international traffic. It is calculated for the hours 2100 to 0500 GMT. For each hour and each center four entries are made: first, the total of scheduled air carrier and general aviation demand is entered in the DEMAND column; to this is added the aircraft held on the ground from the previous hour, and the sum entered under TOT DEMAND; the amount by which this exceeds the QUOTA entry gives number HELD ON GND. It should be noted that the center allocations here are not assigned by any formula but based on the experience and judgment of the flow controller, with the condition

TABLE 1

MANUAL AFCP SAMPLE DEMAND CHART FOR LGA

HR GMT	SUN	MON	TUE	WED	THUR	FRI	SAT
09	0	1	1	1	1	1	1
10	1	1	1	1	1	1	1
11	0	3	3	3	3	3	2
12	2	19	19	19	19	19	15
13	10	24	23	24	24	24	19
14	21	23	24	23	23	23	20
15	23	26	26	26	26	26	23
16	21	25	25	25	25	25	21
17	24	24	24	24	24	24	23
18	20	23	23	23	23	23	18
19	31	29	31	31	31	31	25
20	24	25	25	25	26	25	19
21	28	31	28	28	27	28	19
22	26	26	26	26	26	26	25
23	33	33	33	33	34	33	24
00	23	23	24	23	23	23	18
01	29	29	28	29	29	29	20
02	24	24	24	24	24	24	15
03	11	11	11	10	11	11	7
04	5	5	5	5	5	5	3
05	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0
TOTAL AFCP.	218	220	219	219	220	219	163
24 HR.	356	405	404	403	405	404	316

TABLE 2

MANUAL AFCP SAMPLE FLOW RATE CHART

GMT HOUR	ACFT. PREV. DELAYED	ACCPT RATE	NO. OF DELAYED ACFT IN EXCESS OF ACCPT RATE	AMOUNT OF A/RESERVATION AVAILABLE FOR DEMAND ACFT	DEMAND THIS HOUR	NO. OF ACFT TO BE DELAYED	ACTION ON DELAYED ACFT.	
							HELD IN N.Y. CTR	HELD ON GROUND
19	2	24	0	22	31	9	9	0
20	9	24	0	15	26	11	11	0
21	11	24	0	13	27	14	14	0
22	14	24	0	10	26	16	16	0
23	16	24	0	8	34	26	20	6
00	26	24	2	0	23	25	24	1
01	25	24	1	0	29	30	24	6
02	30	24	6	0	24	30	24	6
03	30	24	6	0	11	17	17	0
04	17	24	0	7	5	12		
05	12	24	0		0			
06					0			

TABLE 3 MANUAL AFCP SAMPLE ALLOCATIONS

		DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND
		2100				2200				2300				0000				0100			
I	BOS	3	3	3	0	5	5	3	2	2	4	2	2	1	3	2	1	5	6	1	5
	NYC	1	1	0	1	1	2	1	1	0	1	1	0	0	0	0	0	1	1	0	1
	DCA	0	0	0	0	1	1	1	0	3	3	2	1	0	1	1	0	2	2	0	2
	JAX	0	0	0	0	1	1	0	1	0	1	1	0	1	1	0	1	0	1	1	0
	CLE	1	1	1	0	2	2	2	0	3	3	1	2	0	2	2	0	1	1	0	1
	CHI	1	1	1	0	2	2	1	1	1	2	1	1	1	2	0	2	0	2	2	0
	ATL	1	1	1	0	1	1	1	0	2	2	0	2	1	3	2	1	1	2	1	1
	IND	1	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	2	2	0	2
	YZ	0	0	0	0	1	1	0	1	0	1	1	0	1	1	0	1	1	2	1	1
	UL	2	2	1	1	0	1	1	0	1	1	0	1	1	2	1	1	0	1	1	0
		10	10	8	2	14	16	10	6	13	19	9	10	6	16	9	7	13	20	7	13
II	MIA	5	5	5	0	4	4	4	0	3	3	0	3	5	8	3	5	5	10	4	6
	HOU	2	2	2	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
	FTW	2	2	1	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0
	MEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
	KCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
	MSP	0	0	0	0	2	2	1	1	0	1	1	0	2	2	0	2	1	3	2	1
	DEN	0	0	0	0	2	2	0	2	0	2	2	0	0	0	0	0	0	0	0	0
		9	9	8	1	9	10	6	4	3	7	4	3	8	11	3	8	8	16	7	9
III	ABQ	2	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	LAX	3	3	3	0	1	1	1	0	7	7	3	4	4	8	4	4	1	5	3	2
	SLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SEA	2	2	1	1	1	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0
	OAK	3	3	3	0	5	5	3	2	4	6	2	4	0	4	4	0	2	2	0	2
	GTF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		10	10	8	2	7	9	6	3	11	14	6	8	4	12	8	4	3	7	3	4
IV	BOS	9	9	9	0	8	8	5	3	3	6	4	2	4	6	2	4	2	6	3	3
	NYC	5	8	4	1	2	3	2	1	4	5	2	3	4	7	3	4	2	6	3	3
	DCA	4	4	3	1	1	2	1	1	2	3	1	2	3	5	1	4	2	6	3	3
		18	18	16	2	11	13	8	5	9	14	7	7	11	18	6	12	6	18	9	9
	TOT.	47	47	40	7	41	48	30	18	36	54	26	28	29	57	26	31	40	61	26	35
	MGD.	+45				+45				1 + 05				1 + 15				1 + 25			

TABLE 3 (CONTINUED)

		DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND	DEMAND	TOT DEMAND	QUOTA	HLD ON GND
		0200				0300				0400				0500			
I	BOS	2	7	4	3	4	7	3	4	2	6	5	1	4	5	4	1
	NYC	0	1	1	0	3	3	0	3	1	4	3	1	3	4	4	0
	DCA	1	3	1	2	0	2	2	0	2	2	0	2	0	2	2	0
	JAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	CLE	0	1	0	1	1	2	1	1	2	3	2	1	0	1	1	0
	CHI	2	2	0	2	0	2	2	0	1	1	0	1	1	2	1	1
	ATL	1	2	1	1	1	2	1	1	0	1	1	0	0	0	0	0
	IND	1	3	1	2	0	2	2	0	0	0	0	0	0	0	0	0
	YZ	0	1	1	0	1	1	0	1	0	1	1	0	0	0	0	0
	UL	1	1	0	1	0	1	1	0	1	1	0	1	0	1	1	0
		8	21	9	12	10	22	12	10	9	19	12	7	8	15	13	2
II	MIA	1	7	5	2	0	2	1	1	0	1	1	0	6	6	5	1
	HOU	2	2	0	2	0	2	1	1	0	1	1	0	0	0	0	0
	FTW	3	3	0	3	0	3	1	2	0	2	2	0	0	0	0	0
	MEM	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	KCK	1	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0
	MSP	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
	DEN	1	1	0	1	0	1	0	1	0	1	1	0	0	0	0	0
		8	17	7	10	0	10	5	5	0	5	5	0	6	6	5	1
III	ABQ	1	1	0	1	0	1	0	1	0	1	1	0	0	0	0	0
	LAX	1	3	2	1	1	2	1	1	1	2	1	1	3	4	3	0
	SLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SEA	1	1	0	1	0	1	0	1	0	1	1	0	0	0	0	0
	OAK	2	4	1	3	0	3	2	1	2	3	1	2	0	2	2	0
	GTF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		5	9	3	6	1	7	3	4	3	7	4	3	3	6	5	1
IV	BOS	1	4	2	2	0	2	2	0	1	1	1	0	3	3	2	1
	NYC	4	7	3	4	1	5	2	3	1	4	3	1	0	1	1	0
	DCA	1	4	2	2	0	2	2	0	1	1	1	0	0	0	0	0
		6	15	7	8	1	9	6	3	3	6	5	1	3	4	3	1
	TOT.	27	62	26	36	12	48	26	22	15	37	26	11	20	31	26	5
	MGD.	1 + 25				+55				+45				+45			

that they add up to the total estimated acceptance rate. The maximum ground delay, MGD, in hours, is the total number held on the ground divided by the QUOTA for the subsequent hour. It is rounded up to the next higher multiple of five minutes, and is never less than 45 minutes, in the present example.

From the above examination of the manual AFCP procedures, four facts emerge:

1. The manual AFCP were designed to maintain a one hour hold over New York while they are in effect.
2. The individual center quotas were allocated manually on the basis of experience and judgment rather than by formula.
3. The maximum ground delays were calculated approximately from the number delayed and the acceptance rate.
4. Assignment of specific arrival times and the implementation of the 15-minute rule were left to the centers receiving AFCP allocations.

The computerized AFCP, to be described next, differs from the manual AFCP in the first three respects but agree with them and with the FAA Orders in the fourth.

THE AFCP COMPUTER PROGRAM

The computer program that automates the Advanced Flow Control Procedures was constructed by MITRE Corporation under FAA direction during 1969. It was put into operation about January 1970. It is run on the IBM 9020 Simplex (roughly equivalent to an IBM 360/50) at the Kansas City ARTCC. It is connected via discrete TTY to the Airport Reservation Office (ARO) in Washington, D.C. and via the CENTER B circuit to all the ARTC Centers.

The program does reservations bookkeeping and flow control processing. About half of the source listing is devoted to I/O, message checking, formatting, utility and startup routines; about a third is devoted to setting up and maintaining the flight reservations file; and about one sixth to allocating new slots for AFCP. These functions are described in detail in References 1 through 3. How the computer program interacts with the ARTCC flow controller during AFCP will be described in the next section; the present discussion deals with those internal operations of the program that bear on the effectiveness of the AFCP. The following description is based on References 1 through 3, and the source listing, Reference 4.

The operations performed by the flow control processing program may be summarized as follows:*

1. A demand file is built up for each high density airport. It contains the scheduled air carrier, air taxi, general aviation, additional quota air carrier, charters, ferry training, and air carrier extra section flights. These are sequenced in order of PTA at the airport, subsequenced in order of departure time, and, if necessary, further subsequenced in order of receipt of the reservation.
2. A tentative arrival time, also called a tentative assigned time of arrival, or TATA, is computed for each flight. This time is based on the average interval between landings obtained from the estimated hourly capacity of the airport, and the demand list; a flight's TATA is the beginning of the earliest interval in which it can be accommodated.
3. An assigned time of arrival (ATA) is calculated for each flight at least 75 minutes prior to its PTD. The ATA is set equal to the TATA or PTA, whichever is later, and is not changed because of subsequent reservations. It may be changed, however, if the PTA is changed.
4. If, in any hour, the TATA exceeds the PTA by 60 minutes or more, a message is sent to the NYARTCC recommending that AFCP begin on the hour of the PTA.
5. If a BEGIN AFCP message is received by the computer from the NYARTCC, the TATA's are counted up by center and by hour, starting at the hour specified in the message from New York, and are issued on Service B as the AFCP allocations. All centers within a zone receive notice of the allocations for that zone.
6. The assigned times of departure are calculated as:

$$\text{ATD} = \text{ATA} - \text{ETE} - \text{DLYTME}$$

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* Samples of AFCP-related messages that the program receives and transmits are listed in Appendix B, which is extracted from Reference 3, Volume 6. It should be pointed out that the MAX DELAY and DLY of messages 4, 6, and 16 are just the maximum differences between TATA and PTA described in step (4). The MAXIMUM GROUND DELAY, MAXIMUM ENROUTE DELAY, and GRD DELAY of messages 11, 12, 14, and 16 are all equal to the maximum of the differences between the ATD's of step (6) and the original PTD's.

where DLYTME is the maximum delay time (ATA - PTA) allowed before the initiation of AFCP. It is presently preset to 60 minutes, as in Paragraph 4 above. The ATD's are not usually issued to the ARTCC's.

A careful examination of the above process reveals that the resultant air delays at New York may lie anywhere between zero and one hour and, in some cases, may exceed one hour. Moreover, the individual center allocations that are issued by the program are based on the TATA list and are inconsistent with the actual traffic. Both of these difficulties are directly traceable to the New York air delays in the hour immediately preceding the initiation of AFCP, and to the one hour quantization of the allocations.

These conclusions can be verified by a simple example, worked out in Table 4 and illustrated in Figure 1. Each column of the table corresponds to a step in the process. The first column listed the flights scheduled from 1700 through 2000, in order of the PTA. A uniform schedule of 10/hour is assumed for simplicity. The second column shows the capacity estimate of 6/hour, which will be assumed to be accurate so as to eliminate the effect of capacity estimation errors. The third column shows the TATA list made up by the computer, which places each flight in a landing slot according to the estimated capacity. The computer then calculates the arrival delay for each flight, shown in column four. It scans this column and detects that the estimated air delay in New York will exceed 60 minutes for flight #16. It then recommends AFCP to the NYARTCC flow controller, to begin at 1800, the hour in which the PTA of flight #16 falls. The controller may accept, reject or alter this recommendation, so that AFCP may be initiated on any hour. It is assumed in Table 4 that NYARTCC initiates AFCP at the 1800 hour, as recommended. The computer then accesses the TATA list, starting at 1800, and issues the total allocations shown in column six, but broken out by center. These allocations will affect arrivals in the 1800 and 1900 hours, as shown in column 7. The arrivals in parenthesis would be obtained if the total allocation for each arrival hour were released by the centers so as to arrive as early in the hour as possible, consistent with the PTA's. This is allowed by the FAA orders, except for the 15 minute rule. The actual landings (column 9) and the New York Air delays (column 10) are obtained by applying the actual capacity (column 8) to the available arrivals.

It can be seen from column 10 that the air delays for this example reach a steady 40 minutes when the allocated arrivals are spread throughout the hour, and oscillate if they are bunched at the beginning of the hour. The reason can be seen in Figure 1. This is a plot of the cumulative arrivals and landings at New York center, corresponding to the example of Table 4. The figure shows the cumulative scheduled arrivals of column one and the

TABLE 4. EXAMPLE OF PRESENT COMPUTERIZED AFCP PROCESS

GMT HOUR	COL 1 SCHEDULED ARRIVALS (PTA'S)	COL 2 ESTIMATED CAPACITY	COL 3 ESTIMATED LANDINGS (TATA'S)	COL 4 ESTIMATED AIR DELAY (MIN)	COL 5 AFCP STATUS	COL 6 AFCP TOTAL ALLOCATIONS	COL 7 AVAILABLE ARRIVALS*	COL 8 ACTUAL CAPACITY	COL 9 ACTUAL LANDINGS	COL 10 NY AIR DELAY (MIN)
1700	Flight # 1		Flight #				Flt # 1 (1)**		Flight #	
	2		1	4			2 (2)		1	4 (4)
	3		2	8			3((3)		2	8 (8)
	4						4 (4)			
	5		3	12	NO	NONE	5 (5)		3	12 (12)
	6	6	4	16	AFCP	ISSUED	6 (6)	6	4	16 (16)
	7						7 (7)			
	8		5	20			8 (8)		5	20 (20)
	9		6	24			9 (9)		6	24 (24)
	10						10 (10)			
1800	11						(11)			
	12		7	28			11 (12)		7	28 (28)
	13		8	32			(13)		8	32 (32)
	14				FIRST		12 (14)			
	15	6	9	36	AFCP	6	13 (15)	6	9	36 (36)
	16		10	40	HOUR		14 (16)		10	40 (40)
	17									
	18		11	44			15		11	40 (44)
	19		12	48			16		12	40 (48)
	20									
1900	21						(17,18,19,20,21)			
	22		13	52			17 (22)		13	40 (52)
	23		14	56			18		14	40 (56)
	24				SECOND					
	25	6	15	60	AFCP	6	19	6	15	40 (60)
	26		16	64	HOUR		20		16	40 (64)
	27									
	28		17	68			21		17	40 (44)
	29		18	72					18	40 (54)
2000	30						22			

*Available to land but not necessarily landed. See footnote on p. 24.

**The numbers in parenthesis apply if the entire hour's allocation is dispatched so as to arrive at the beginning of the hour, but not before scheduled.

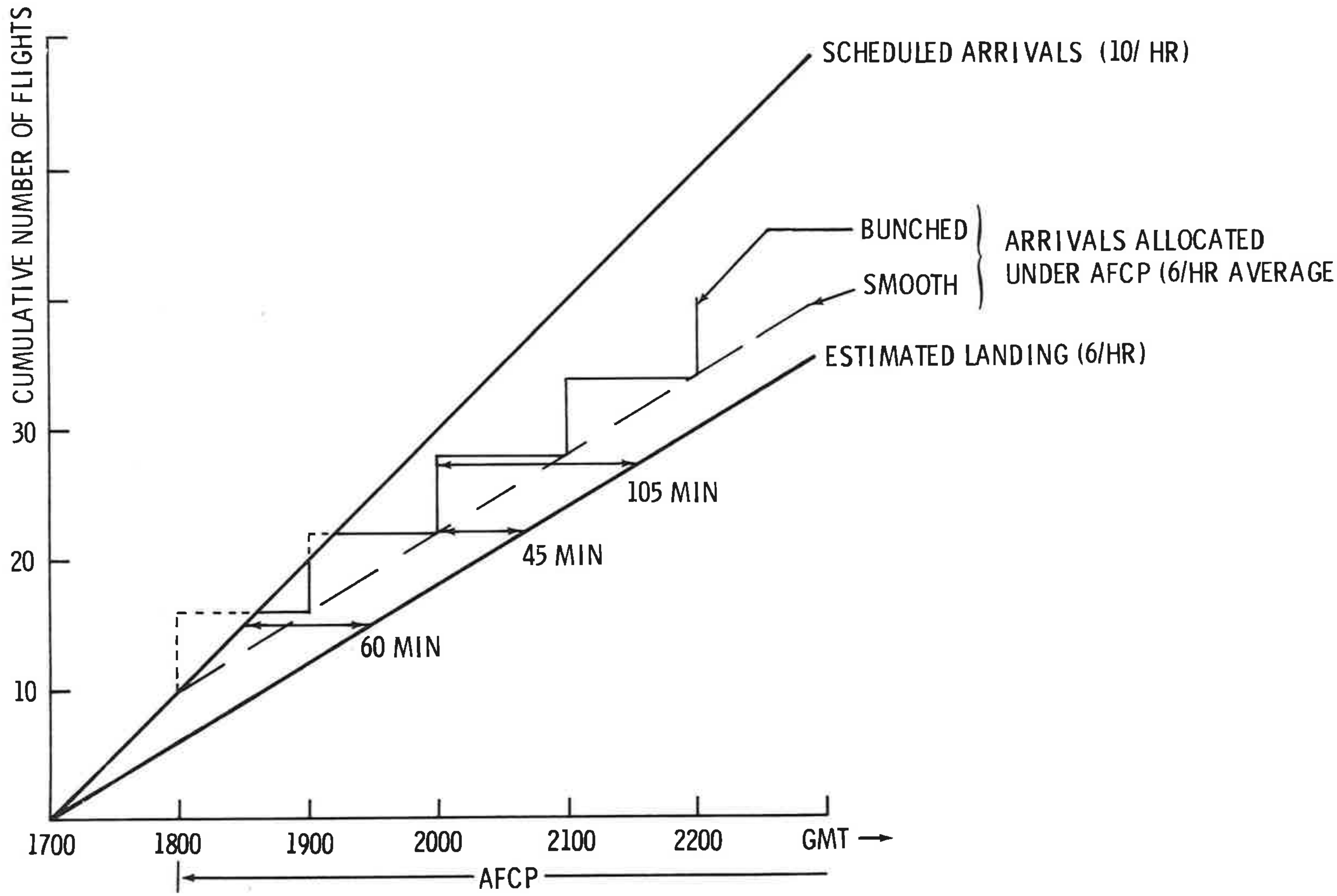

Figure 1. Cumulative Plot of Arrivals and Landings for AFCP Example of Table 4

cumulative landings for the estimated capacity of column two. The horizontal distance between these two lines represents air delay for a particular aircraft, on a First-Come-First-Served basis, and assuming it arrived according to schedule and landed according to estimated capacity. This delay reaches 60 minutes for the 15th flight, and exceeds it for the 16th, as shown in the figure and the table. AFCP is initiated at the beginning of the hour in which flight 16 is scheduled to arrive. The air delay at that time (1800) is 45 minutes, but in general, it depends on the value of the scheduled arrival curve at the start of AFCP. The total allocations, if applied uniformly throughout the hours, would limit air delays to 45 minutes from 1800 onward. If, however, the allocations were bunched at the beginning of each hour, the arrivals would form the step function shown, and air delay would oscillate between 45 and 105 minutes.

Another problem, however, can be seen from the figure. The individual center allocations are drawn by the computer program from the TATA list, which corresponds to the estimated landings curve. For the 1800 hour, for example, the allocations issued to the centers correspond to the 7th through 12th flight. But in reality all flights up to and including the 10th are not under AFCP and will have reached ZNY before it starts at 1800. The allocations should be drawn from flights 11 through 16. Thus, although the total allocation is correct, the individual center allocations are drawn from the wrong part of the demand list. Since the relative demand varies from hour to hour, this will cause inequities, and increase the swapping burden on the centers.

A simple solution to these problems is individual flight dispatching, drawn from the TATA list starting with the first flight with over one hour delay. The assigned departure time would accompany each flight ID.

An alternate solution is to issue cumulative rather than hourly allocations, referenced to some fixed time early in the arrival morning. This would control the initial delay at New York. To control the arrival bunching, or waves, it would be necessary to issue, say, 20-minute allocations, or to stagger the present hourly allocations among the centers.

Yet another solution is to initiate AFCP not on the hour, but at whatever time the anticipated delay reaches the reference level. Again, a reduced or a staggered allocation interval would be required to avoid the problem of arrival waves.

The relative advantages of these solutions will be discussed later in the FINDINGS AND RECOMMENDATIONS.

It will be appreciated that the above example is idealized in some ways. The schedule and capacity are not constants and there are departure and enroute delays, but one cannot expect these uncontrollable effects to improve a scheme that does not function properly without them. In fact, the simulation results to be described in the section entitled SIMULATION STUDY show unpredictable delays and arrival waves even when these effects are taken into account.

ATC PROCEDURES USING THE COMPUTER PROGRAM

The KC computer program has been operating in conjunction with the ARTCC and HQ flow controllers since January 1970. This section describes the over-all procedures as determined by discussion with the NYARTCC and HQ personnel, and by the pertinent orders and records.

The AFCP start at the New York Center. The NYARTCC flow controller, usually the assistant watch supervisor on the 2300 - 0700 shift (local time), takes the following actions:

1. He checks all available weather data, both present and forecast. Discussions with NYARTCC personnel indicate that they regularly avail themselves of JFK and LGA tower observations, JFK, LGA, and NYARTCC forecasters, as well as forecasts by FWS at University Heights, New York, and by the airline forecasters.
2. He checks with appropriate towers and the New York Common IFR Room (CIFRR) for runway configurations, estimated landing capacity, special operations, or any other condition that might impede expeditious traffic flow.
3. He checks Navaids and landing systems operational status.
4. In conference with the CIFRR and the appropriate towers an hourly acceptance rate is established. It is recorded in the Flow Control Log.
5. This acceptance rate is transmitted to the Simplex 9020 computer in Kansas City. The computer has the demand for that day based on scheduled air carrier operations and updated information from the Airport Reservation Office (ARO) as previously described. The program issues a recommendation to the NYARTCC for those hours that it anticipates AFCP will be required. See messages 1 through 7 of Appendix B.
6. In practice, the 2300 0700 flow controller will wait and confer with his relief, the 0700 - 1500 flow controller, and a decision will then be made as to AFCP implementation. If affirmative, a message will be sent via service B to all centers outlining the hours of AFCP, the hourly allotments for each center and the delay to be expected. See messages 8 through 19 of Appendix B.

There is only one criterion used by the New York flow controller for determining the implementation of AFCP; i.e., when arrival delays are anticipated to reach one hour, in other words, a backlog of one hour's traffic, and continuing for several hours.

In order for AFCP to be effective, the aviation community is notified as far in advance as is practical. ARTCC's have been zoned as follows:

Zone I

a. Boston
b. New York
c. Washington
d. Jacksonville
e. Cleveland
f. Chicago
g. Indianapolis
h. Atlanta
i. Canada (eastern area)

Zone II

a. Miami
b. Houston
c. Memphis
d. Kansas City
e. Minneapolis
f. Denver
g. Fort Worth

Zone III

a. Albuquerque
b. Los Angeles
c. Salt Lake City
d. Great Falls
e. Seattle
f. Oakland

Zone IV

a. Boston Oceanic
b. New York Oceanic
c. Washington Oceanic

Zone I - Notified four hours before aircraft are scheduled to arrive at destination.
Zone II - Notified six hours before aircraft are scheduled to arrive at destination.
Zone III - Notified eight hours before aircraft are scheduled to arrive at destination.
Zone IV - Notified four* hours before effective at destination.

Each ARTCC has a flow control position. Upon receipt of an AFCP message, the flow controller should set up and maintain a sequence board for LGA and JFK airports based on proposed time of arrival. He should provide a duplicate strip for each proposed flight originating in his center's area and destined, nonstop,

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* According to the computer program, as stated in Reference 3, Volume 6, paragraphs 2-5, 6. The FAA Order 7230.10 calls for two hours notice (page 3, paragraph 7.b(4) (d)).

for LGA or JFK. Aircraft will then be dispatched based on the flow controller's interpretation of the allocations. Also, upon receipt of BEGIN AFCP message, the flow controllers in all zones notify their respective flight service stations that AFCPs are in effect for aircraft destined for LGA, and/or JFK airports, and specify maximum ground delays for each hour as noted in the AFCP messages. This may be done via Service B or Service F at the option of the center. The flow controller also notifies the terminals that generate traffic for the two named airports. Air carrier operations are notified of this information by New York Center through Aeronautical Radio Incorporated at New York.

The following have been designated coordination centers:

- New York Center: All of Zone I and IV
- Houston : Houston, Miami, Memphis, and Ft. Worth
- Kansas City : Kansas City, Denver, and Minneapolis
- Oakland : All of Zone III

Each coordination center is responsible for release of or request for additional allocations among the centers within its group. It is the sole responsibility of the coordination centers to request additional allocations on the basis that there are aircraft which exceed the maximum ground delay as specified in the AFCP message. It is also the sole responsibility of the coordination center to reallocate surplus allocations within its designated group. In the event allocations can be released or additional slots are needed by the group, the coordination center contacts the New York Center with such release or request. All centers should release unused slots for a particular hour as soon as ATD's for that hour have been assigned. The users have been requested to file IFR flight plans at least an hour and a half prior to proposed departure when destined for JFK or LGA.

During visits to NYARTCC, TSC queried several flow controllers and watch supervisors about their experience with AFCP and the computer program in particular. Several impressions resulted:

1. Extensive coordination with CIFRR and weather forecasters has improved capacity estimation.
2. The flow controllers are wary of the possibility of lost capacity if AFCP are implemented unnecessarily.
3. There is a need in NYARTCC for better understanding of the KC computer program, particularly the MGD (Maximum Ground Delay) and MAX DELAY outputs.
4. The KC computer was down on one of the two visits.
5. Restrictions are sometimes used with AFCP.

The fear of lost capacity (2) and lack of familiarity with the program (3) provide reason to believe that the computer recommendations to implement AFCP are often modified by the judgment of the NYARTCC flow controller.

MEASURES OF EFFECTIVENESS

In order to determine how well AFCP achieves its objectives, one must first state those objectives quantitatively. The FAA Orders, as analyzed in a previous section, suggest the following measures:

1. Total air delay (aircraft hours) in New York Center in excess of one hour.
2. Distribution of ground delays among users.
3. Distribution of air delays among users.
4. Total holding (aircraft hours) outside New York Center.
5. Total air delays (aircraft hours) in New York Center, provided sufficient demand is maintained to preclude unnecessary gaps in the landings.
6. Accuracy of arrival delay prediction.

To these one might add:

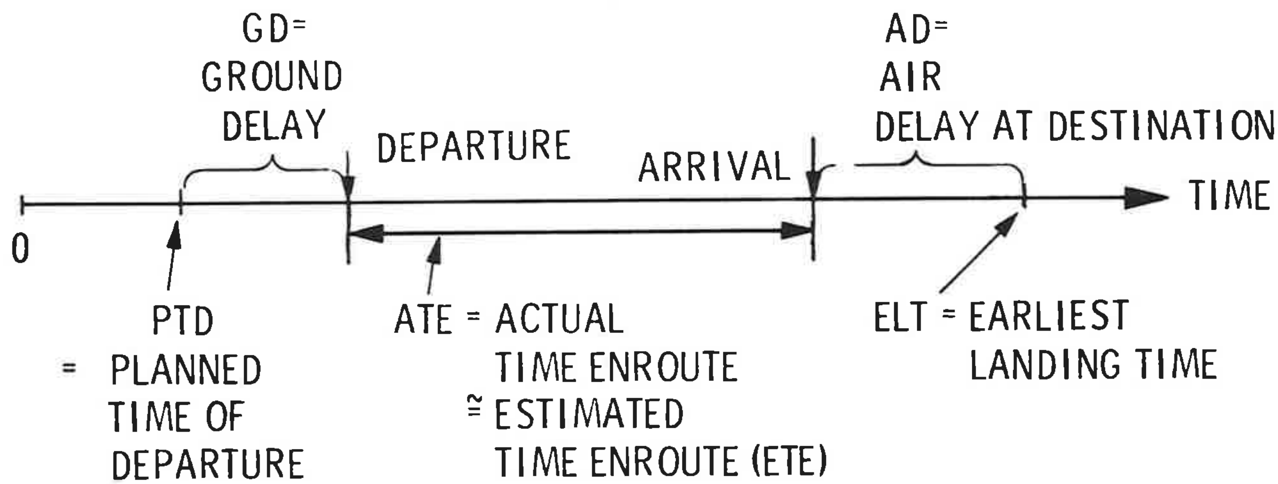
7. Number of aircraft diverted.
8. Number of flights to LGA or JFK cancelled due to arrival delays.

The present study analyzed the above eight measures and reduced them to quantitative terms where possible.

TOTAL AIR DELAY IN NEW YORK CENTER

In considering the eight measures listed, several considerations should be borne in mind. First, is that the earliest possible landing time for each flight is determined, not by flow control, but by the schedule, the time enroute, the runway capacity of the airport, and the first-come-first-served (FCFS) rule. AFCP can shift delay from air to ground, and vice versa, but the total air plus ground delay has a (minimum) value predetermined for each flight by those four factors, illustrated in Figure 2. Since the air delay plus ground delay is approximately constant, it cannot serve well as a measure of effectivness. The air delay alone, however, is an effective measure of how well AFCP has shifted delays from air to ground. Thus we have:

J_1 = total aircraft hours lost in the air by aircraft arriving at New York.



ELT = FIXED BY RUNWAY ACCEPTANCE RATES

PTD = FIXED BY PUBLISHED SCHEDULE

ATE = FIXED, APPROXIMATELY, BY CONDITIONS GENERALLY UNCONTROLLABLE BY AFCP

THUS GD + AD $\cong$ ELT - PTD - ETE

= FIXED, APPROXIMATELY, BY CONDITIONS UNCONTROLLABLE BY AFCP

Figure 2. Relation of Ground Delay, ETE, and Air Delay

This measure is illustrated in Figure 3. It is the area between the two curves, cumulative available arrivals* and cumulative actual arrivals.

CANCELLATIONS

A second consideration is that cancellations are probably made on the basis of local weather conditions and of the individual airline's assessment of the delays to be experienced by its flights. It seems unlikely that any intended apportionment between air and ground would greatly reduce the number of cancellations. Long waits for take-offs can have a negative effect on patronage, thus making cancellations more attractive to the carriers. Also, cancellations reduce the number of aircraft in the air and reduce the total delay time. Since it is difficult to tell whether the number of cancellations would increase or decrease because of ground holds, it appears that cancellations are a poor measure of effectiveness (or ineffectiveness) of AFCP.

LOST CAPACITY

Another consideration is that the main purpose of the one hour air delay is to prevent unnecessary gaps in the landing sequence. A necessary gap is one caused by runway capacity limitations or by a corresponding gap in the schedule. An unnecessary gap is one caused by AFCP's failure to deliver aircraft to the full capacity of the runway and the schedule. Unless some other intrinsic value can be ascribed to the one hour air hold, then, it can be replaced by a measure of unnecessary gaps in landings. Such a measure is now discussed.

Consider the stream of 20 aircraft shown in Figure 4a. It is to be assumed, for illustration, that the available arrival* rate and scheduled arrival rate are both 10/hour for the first

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* By available arrival time here is meant the earliest time that the aircraft could have reached the gate, given no delays in the New York Center. It will be marked by an asterisk henceforth in this report. It will be noted that the use of gate times, as opposed to runway times, for arrival and departure is at variance with 7110.8A, CHG 3, 20. The terminology was selected, nevertheless, because it allows comparison with published airline schedules. The terminology does not affect the results or discussions of this report.

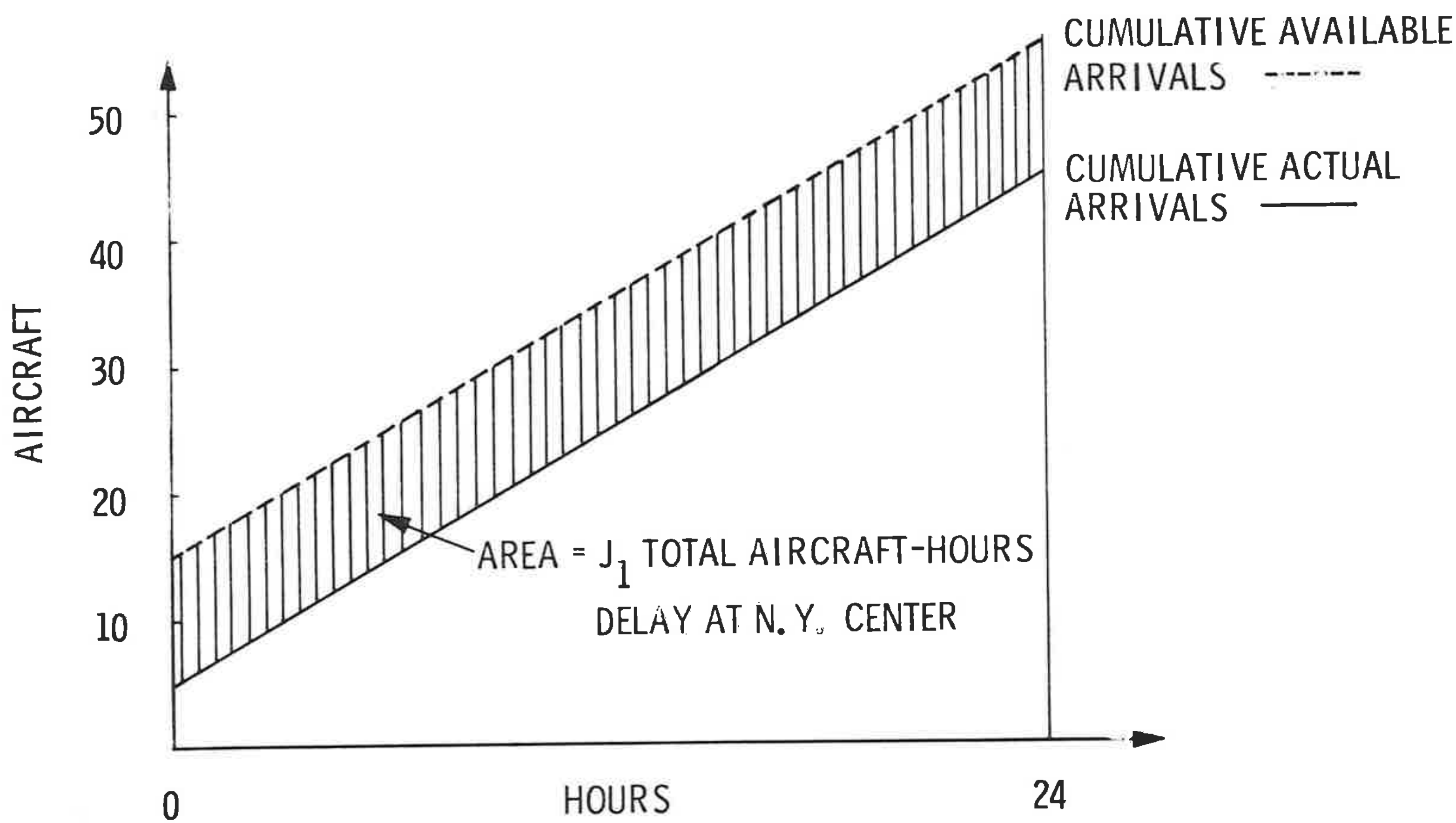

Figure 3. Illustrative Graph of Cumulative Arrivals and Landings

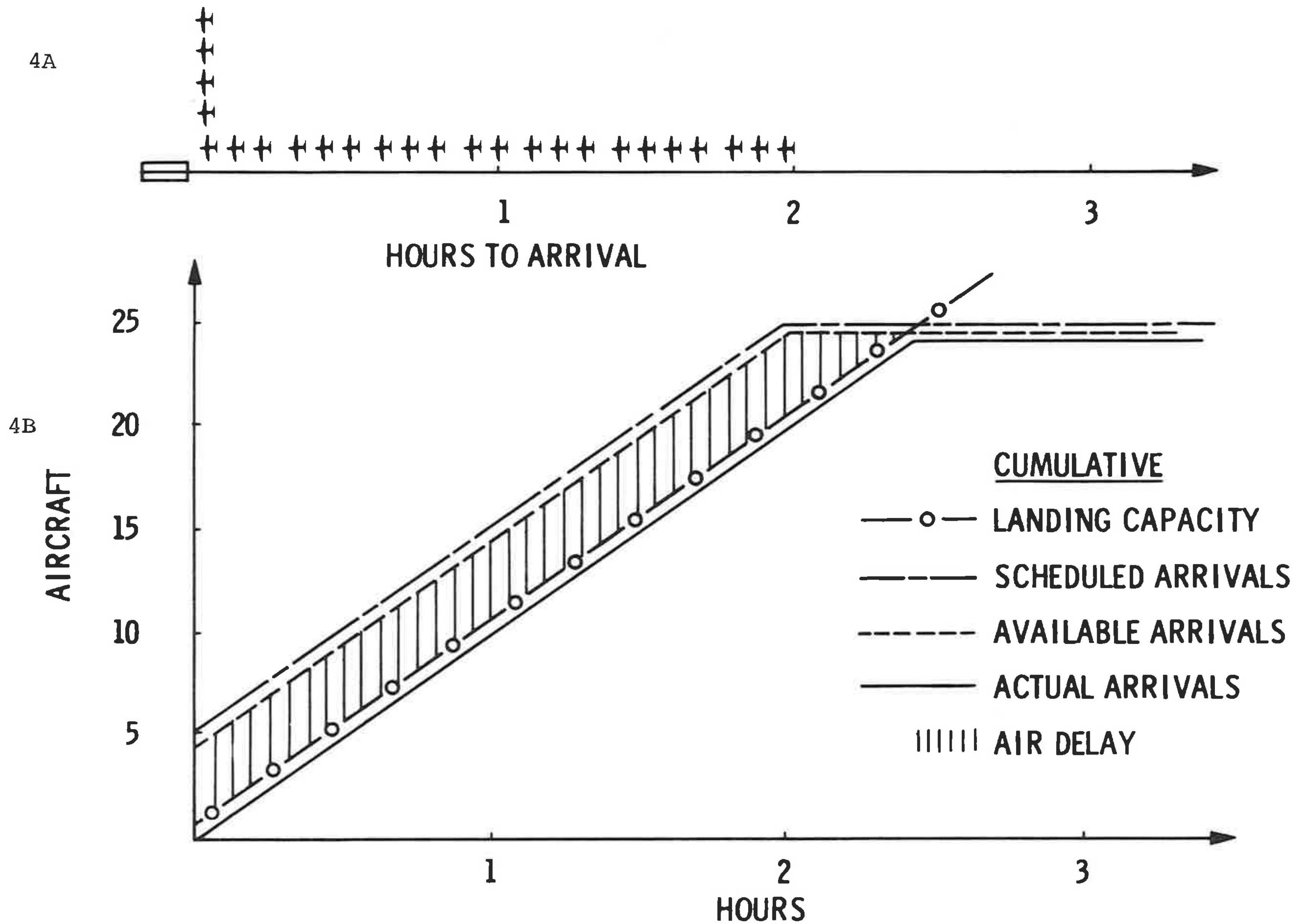

Figure 4. Illustration of Lost Capacity, Step 1

2 hours and 0/hour after that. The landing capacity is 10/hour indefinitely. A total of five aircraft are waiting to land at t = 0 hours, due to previous delays in landing. The cumulative plot for this situation is shown in Figure 4b. The vertically shaded area between the available arrival* curve and the actual arrival curve equals the total aircraft hours spent in the air waiting to land at the terminal.

If, however, a gap is introduced into the aircraft stream, by faulty flow control, as shown in Figure 5a, then the cumulative plots are substantially different, as shown in Figure 5b. In this case, the available arrivals* curve flattens at one hour, and causes the actual arrival curve to flatten starting at 1-1/2 hours. The sudden surge of available arrivals* at t = 2 hours cannot be matched by actual arrivals, which are constrained by the slope of the landing capacity curve. The horizontally shaded area between the landing capacity curve and actual arrivals curve, then, represents capacity lost due to faulty flow control. It is equal to aircraft-hours lost on the ground, prior to reaching the terminal area, assuming no enroute delays.

One further refinement is necessary. If the scheduled arrivals curve falls below the landing capacity curve, as shown in Figure 6, then the achievable landing capacity is reduced. As a result, the capacity lost due to flow control is also reduced, as shown by a reduction in the shaded area of Figure 6. This effect can be taken into account by combining the scheduled arrivals curve and the landing capacity curve into a single curve, labelled USABLE CAPACITY in Figure 7. This curve is defined as one that is limited in magnitude by the scheduled arrivals curve and in slope by the landing capacity curve, plus the conditions that it must equal the scheduled arrivals when the latter coincides with the actual arrivals, and that it be continuous.

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* See note on page 24

5A

5B

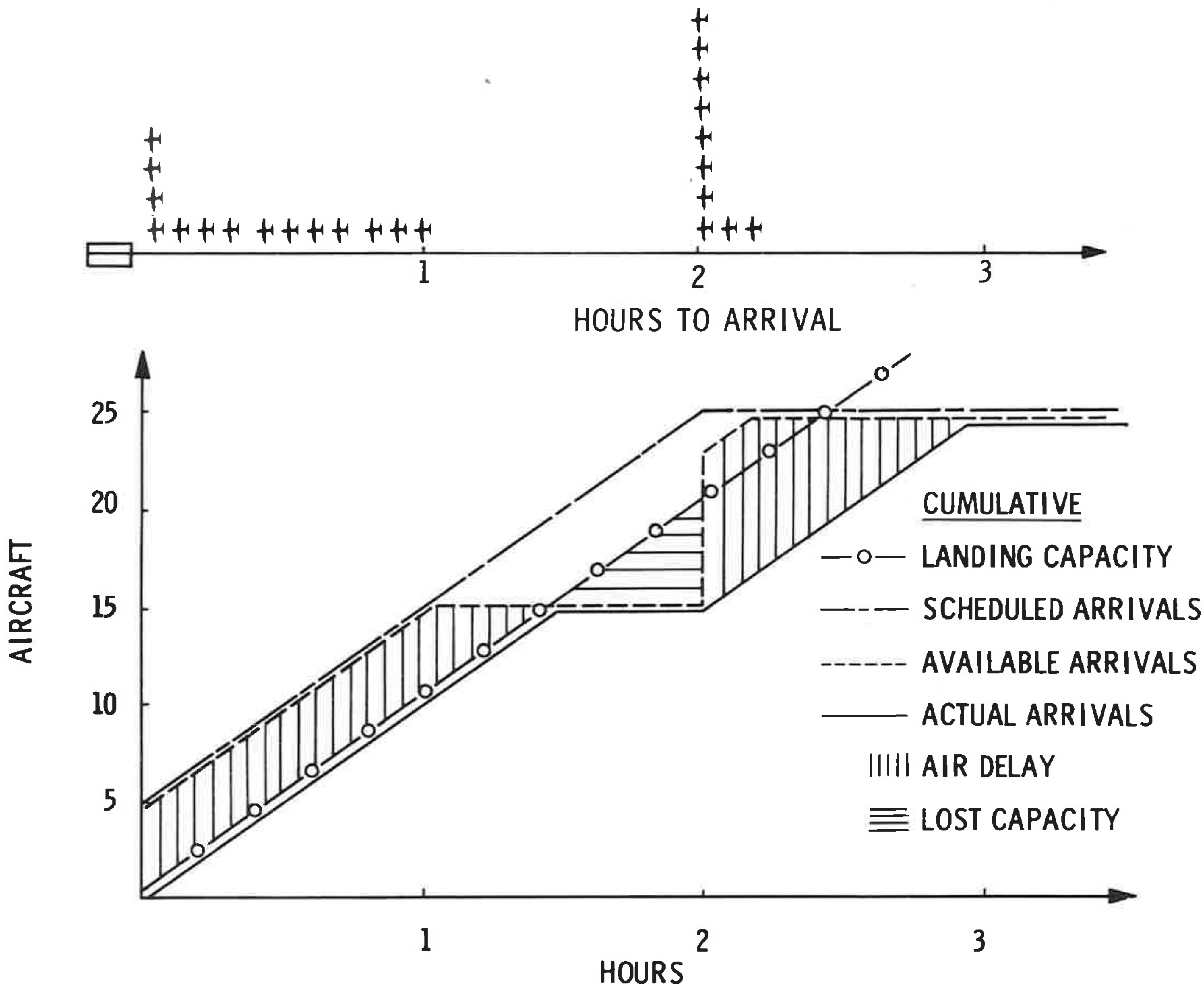

Figure 5. Illustration of Lost Capacity, Step 2

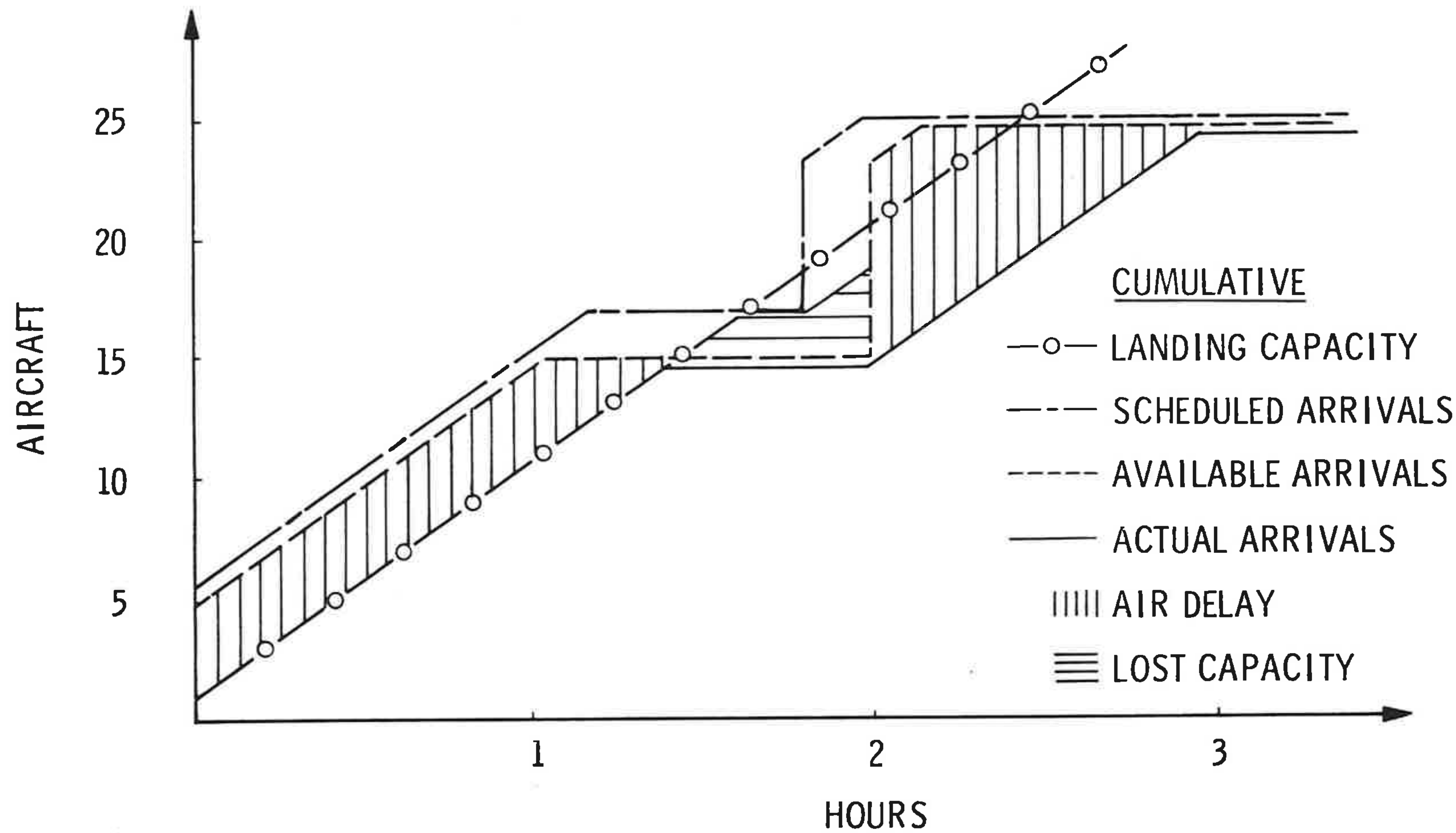

Figure 6. Illustration of Lost Capacity, Step 3

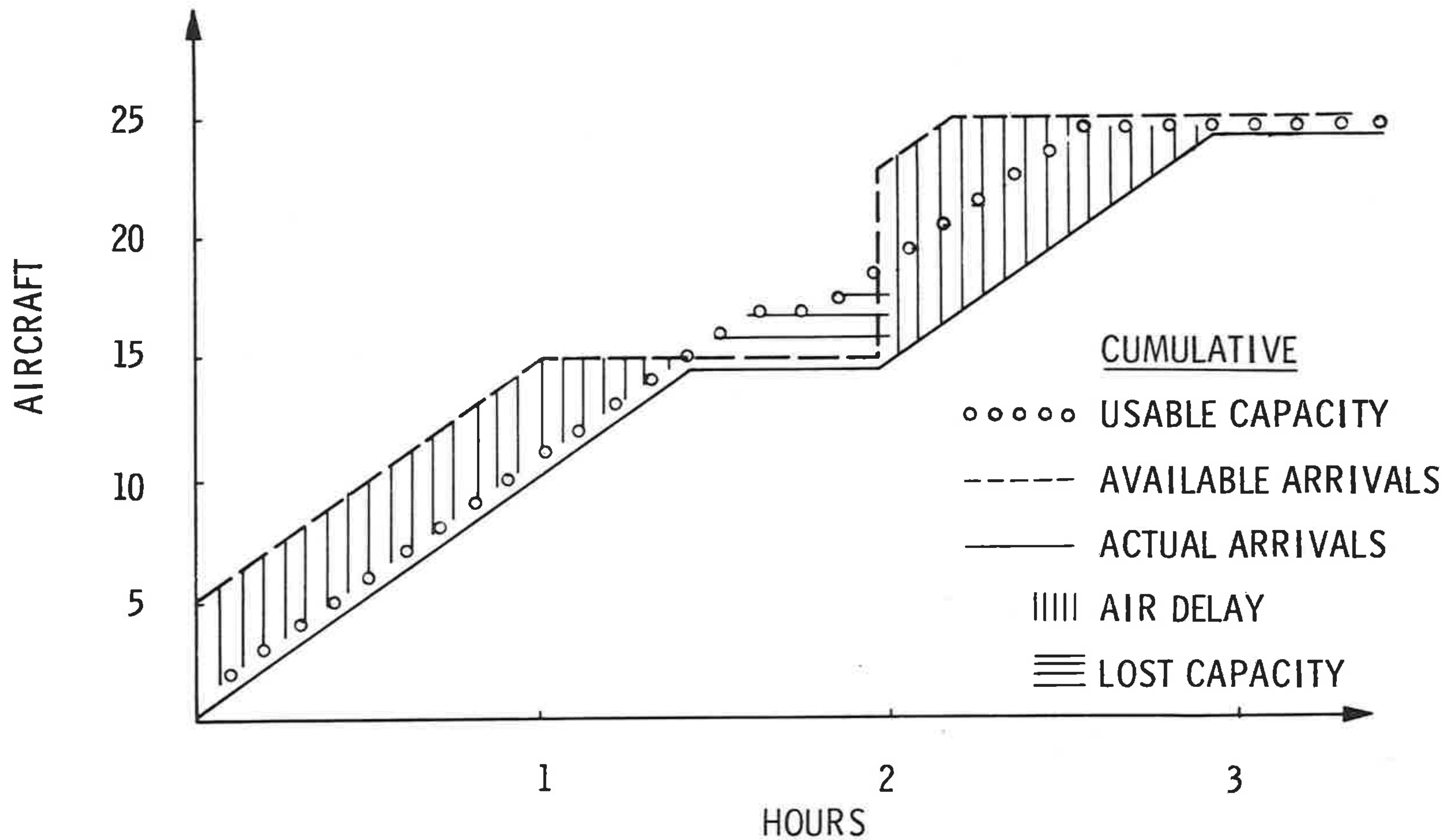

Figure 7. Illustration of Lost Capacity, Step 4

COMBINED MEASURE

One of the major objectives of a flow control scheme, as can be seen from Figure 7, is to cause the available arrivals* curve to coincide with the usable capacity curve, thereby avoiding both air delays (vertically shaded area) and lost capacity (horizontally shaded area). AFCP attempt to control the arrival* curve by controlling departures. If departures are delayed too long, the result is lost capacity; if departures are not delayed long enough the result is air delay. Thus a combined measure may be expressed analytically as Jc,

$$Jc = \int (A(\tau) + L(\tau))\, d\tau$$

where

$$A(t) = \begin{cases} C_A(t) - C_L(t) & \text{if } C_A \geq C_L \\ 0 & \text{if } C_A < C_L \end{cases}$$

= Number of aircraft experiencing arrival delays at the terminal at time t.

$$L(t) = \begin{cases} C_S(t) - C_A(t) & \text{if } C_s \geq C_A \\ 0 & \text{if } C_s < C_A \end{cases}$$

= lost capacity aircraft

and

C_A = cumulative available arrivals*

C_L = cumulative actual arrivals

C_s = cumulative usable capacity, defined above.

This combined measure has the units of aircraft-hours.

DIVERSIONS

An ideal flow control system will deliver aircraft to the runway neither sooner nor later than they can be accepted, and for such a system the combined measure described above will have

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* See note on page 24

a minimum value, zero. How, then, should one score diverted aircraft, which do not reach the destination runway at all? They cannot be ignored as a measure of effectiveness since they are directly related to the terminal delays that AFCP are designed to reduce. On the other hand, it is difficult to ascribe infinite air delay time to a flight, e.g., NA468, that diverted on Feb. 5 from New York Center only four minutes after arriving, never to return under the same flight number that day.

One method of handling diversions in an effectiveness measure is merely to set up a separate measure for them, equal to the number of diverted flights in the time interval of interest. A calculation of effectiveness for situations other than that covered by the February 5 data, then, would operate by rules that generate diversions for each case being studied. Such rules were set up and employed in the VAST simulation program that was used to study AFCP. The results are reported in the section entitled SIMULATION STUDY of this report.

An alternate way of handling diversions is to consider them as holding in the terminal airspace until either they return, under the same flight number, and land at New York, or the end of the time interval of interest occurs, i.e., 0500Z on 6 February. This method equates ground delay at the intermediate airport to air delay over New York for those flights that returned, and it assumes an air delay until midnight for the others. It has the advantage of using the same measure for diversions as for air delays, thus facilitating comparison between alternate AFCP schemes on the basis of total aircraft hours lost. The February 5 data show 23 returnees out of 66 diversions. These data, and the results of the alternate method of treating diversions, are discussed in the Feb. 5, 1971 Case Study.

DISTRIBUTION OF DELAYS

An equitable AFCP system will not only trade off air delays for ground delays, but will insure that all flights receive approximately the same amount of each type of delay. This can be quantified as the spread in the distribution of delays; an ideal system yields delta functions such as in Figure 8a, a poor system yields wide spreads, such as in Figure 8b.

It should be noted that, although air delay plus ground delay is approximately constant* for any given flight, this constant is different for each flight and hence the density

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* Assuming fixed ETE and no lost capacity

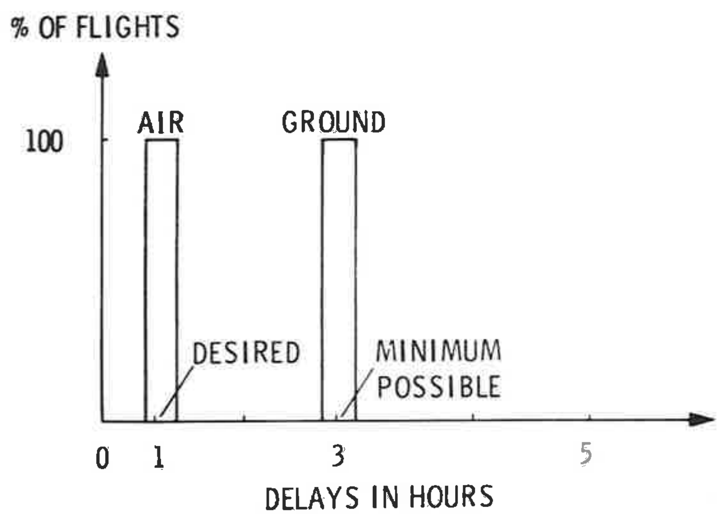

Figure 8a. Distribution of Delays - Ideal Flow Control System

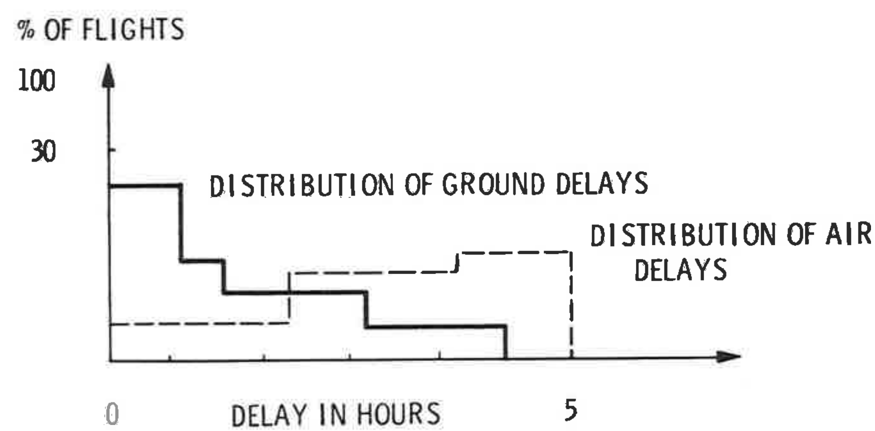

Figure 8b. Distribution of Delays - Poor Flow Control System

distribution of ground delays is not uniquely determined by the density distribution of air delays. Two flow control schemes can result in the same distribution of air delays, but different distributions of ground delays. Hence the two are independent measures of effectiveness*.

Another measure of equitability of delay distribution is the average delay accrued to each carrier. Military and general aviation may be treated as carriers in such a measure. The results of the analysis may be plotted as in Figure 8 if the ordinate is taken to be percent of carriers or number of carriers, and the abscissa average delay.

A third measure may be devised to determine equitability of delay among zones. More generally, the average delay as a function of flight time from New York will indicate whether the delays are distributed equitably among short, medium and long haul flights.

ACCURACY OF DELAY PREDICTION

In addition to reducing air delays, AFCP are aimed at predicting the expected air and ground delays. The predictions are useful to the carriers and pilots in deciding on cancellations, revising equipment schedules, providing adequate fuel reserves, etc., and to the ATC system in allowing adequate staffing, anticipating unsafe situations, etc. The more accurate the prediction, the more useful the information.

AFCP provide a prediction of maximum ground delay (MGD) to all centers. The air delay is understood to have a maximum of one hour. The accuracy of such predictions is easily obtained from plots such as Figure 8. If AFCP were effective, the distributions will show a relatively small percent of flights beyond the stated maximum delay times.

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* If one considers the ground and air delays of each flight as fractions of its total delay, then those distributions are uniquely related and are really the same measure of effectiveness. Mathematically, if X_i, Y_i, and Z_i are ground, air, and total delay for the ith flight, then

$$(X_i/Z_i) + (Y_i/Z_i) = 1 \qquad Z_i \neq 0$$

With this constraint the distribution of (X_i/Z_i) is determined by that for (Y_i/Z_i) and vice-versa. Unfortunately, there is little justification for considering air and ground delays as fractions of the total delay.

AIR DELAY OUTSIDE NEW YORK CENTER

Air delays outside New York Center can arise when ZNY is unable to accept more aircraft and restricts entry so as to back up traffic in adjacent centers. This type of air delay is similar to air delay in New York Center in that it:

1. Causes higher controller workload
2. Interferes with through flights
3. Causes higher operating costs for the user, and higher wait times for passengers
4. Introduces a potential safety hazard

The direct approach to including such delays in a measure of effectiveness is to add them directly to the air delays in ZNY and to the lost capacity. This approach, again, has the advantage of allowing comparison of AFCP schemes on the basis of a single number, equal to aircraft hours. It does not serve well, however, if delays within and without the New York Center cannot be considered commensurable.

SUMMARY

The preceding discussions show that seven of the eight measures of effectiveness proposed at the beginning of this section can, under the stated assumptions, be reduced to just three:

- Combined delay measure
- Distribution of air delays
- Distribution of ground delays

(The first of these encompasses measures (1), (4), (5) and (7) of the original eight; the second encompasses (3) and (6); the third corresponds to measure (2). The measure (8), for the reasons stated, is a poor indicator of AFCP effectiveness.)

- The combined delay measure, Jc, discussed above is here extended to include the time lost by diverted flights, counted as air delay from diversion time up to return or up to midnight, plus the total enroute air delay. This combined delay measure provides a single, gross measure of the effectiveness. It is intended primarily to allow comparison among several AFCP schemes, under identical traffic and capacity conditions, or to determine the effectiveness of a given AFCP scheme under changes in conditions.

- <u>The distribution of air delays</u> here includes three types of distribution:

  1. Number of aircraft vs. length of air delay,
  2. Number of carriers vs. average air delay,
  3. Average air delay time vs. ETE.

  The first of these indicates how successful the control procedures have been in reducing air delays, the ideal distribution having a small mean value and small standard deviation. The second measures whether or not the average delays experienced by the carriers were equitably distributed; again, the ideal distribution shows small mean and small standard deviation, i.e., all carriers with the same small average delay. The third type of air delay distribution, in contrast, should be flat, indicating that the same average air delay was experienced by all flights regardless of distance from New York.

- <u>The distribution of ground delays</u> includes the same three types of curves as the air delays. Their interpretation, too, is the same as for air delays, with one qualification: The average values for the first two distributions cannot be expected to be zero, even for the best flow control scheme.

FEBRUARY 5, 1971 CASE STUDY

DATA SOURCES AND PREPARATION

Once the decision was made to evaluate AFCP, FAA Headquarters sent a message to all enroute centers, the New York CIFRR, JFK and LGA towers requesting that all flight strips, controller logs, flow control logs and any other pertinent data be held for the normal 15 day retention period and then packaged and shipped to the Transportation Systems Center at Cambridge, Massachusetts.

Flight Strip Data

The Center received over 400,000 flight strips that had to be sorted and interpreted to reconstruct the traffic pertinent to AFCP on February 5. Since TSC did not have available manpower for this portion of the task, TSC requested that the responsibility be transferred to the National Aviation Facilities Experimental Center (NAFEC) at Atlantic City, New Jersey and its Technical Facilities Division. A series of discussions was held with Willard O. Bethel, Chief, ATC Enroute Operations Section, and Leo J. Mulry of the ATC Terminal Operations Section, to determine the size of the tasks, NAFEC manpower required, and time frame necessary to satisfy TSC's requirements. The following data, punched out on data cards was determined to be necessary:

columns 1-7 : aircraft ID (EA 1103)

columns 8-11 : aircraft type (B727)

columns 12-14: aircraft filed speed (off flight progress strips) in knots (475)

columns 15-17: terminal of departure (Boston)

columns 18-23: proposed, or airline guide, departure day and GMT (052155)

columns 24-29: actual departure date and GMT (052255)

columns 30-32: entry fix in NYARTCC (HTO)

columns 33-38: arrival time at fix (052306)

column 39: the letter A if the arrival time was actual; the letter E if it was estimated

columns 40-42: destination (JFK or LGA)

columns 43-48: actual landing day and GMT (060006) - wheels on runway

columns 49-54: planned landing day and GMT obtained from the flight strip (052210) - wheels on runway

columns 55-57: distance in n. mi. from entry fix to point of landing. This is the distance an aircraft normally covers, including intermediate fixes and turns, to go from the fix point of columns 30-32 to the point at which the landings of columns 43-54 take place.

columns 58-60: mean speed, in knots, of the aircraft in question in going from the fix point to the landing point. This speed is so selected that dividing it into the distance of columns 55-57 will give the mean time from entry fix to landing, assuming no delays.

NAFEC estimated that it would take six to eight weeks to sort through all the flight strips and records and assemble the data based on a chronological, actual, or estimated arrival time for JFK and LGA. Since the diversions occurred that day, a separate listing of these would be compiled and in place of landing time, a diversion time would be inserted preceded by a minus sign.

NAFEC completed its task on May 6, 1971 and the data cards and printouts were shipped to TSC on May 6, 1971. The flight strips are being retained in storage at NAFEC; however, all logs from pertinent ATC locations were returned to TSC.

Not only all available AFCP data for February 5, 1971, but historical data as well, were obtained during visits to NYARTCC. In addition, some of the controllers who were on duty February 5, 1971 were interviewed and their opinions recorded.

CATER Data

Under contract to the Air Transport Association, Aeronautical Radio Incorporated (ARINC) collect daily data on the JFK operations. This program, called CATER (Collection and Analysis of Terminal Records), was extended in the spring of 1971 to cover all New York Terminal Area operations. Through the cooperation of the FAA, the JFK data for February 5 were made available.

Official Airline Guide (OAG)

From the February, 1971 issue of this publication TSC extracted PTD and PTA for all non-stop air carrier flights destined to arrive at JFK or LGA on Friday, February 5, of both domestic and international origin.

Airport Reservation Office (ARO)

This office has been established to provide IFR reservations service for operations at designated high-density traffic airports, including JFK and LGA. Operators desiring an IFR reservation may contact the Airport Reservations Office direct or any Flight Service Station. Operators cancelling a reservation may do so through any air traffic control facility. Scheduled air carrier flights to and from JFK and LGA do not have to file for a reservation. Unscheduled traffic, general aviation, and military must obtain a reservation. Air carrier cancellations and extra flights are not usually given to the ARO, except as changes in the total number of reservations.

RECONSTRUCTION OF AFCP ON FEBRUARY 5, 1971

Chronology of Events

On the morning of Friday, February 5, 1971, the watch supervisor of the day shift 1200 GMT to 2000 GMT (7 a.m. to 3 p.m. local time) conferred with the team leader of the previous shift. The weather had been and still was below VFR minimums and was forecasted to remain that way for the next twenty-four hours. Light snow had fallen and snow removal and sanding operations had been in effect. Braking action at LaGuardia was fair to poor and causing arrival delays. Calling for the facility status and runway configuration report, he received the following:

1151Z FACILITY STATUS AND RUNWAY CONFIGURATION REPORT

RADAR....... ALL SYSTEMS OPTG AT ACCEPTABLE LEVELS

FREQS...... ALL OPTNL

NAVAIDS..... ALL OPTNL EXCEPT FOR PNE VOR O/S, AND RAV DME O/S

JFK ILS 4 DPTG 4 ACC RTE 28

LGA ILS 4 DPTG 4 ACC RTE 25

EWR ILS 4 DPTG 4 ACC RTE 25

PHL ILS 9 DPTG 9 ACC RTE 20

At 1304Z, he received the following forecast:

WEATHER 1600Z 8 OVRCAST VIS 3 MILES LIGHT RAIN AND FOG WIND 130 DEG 14 KTS &75EE GUSTA VRBL 4 HUNDRD OVRCAST VIS 1 MILE LIGHT RAIN AND FOG

2200Z 5 HUNDRD OVRCAST VIS 2 MILES LIGHT RAIN AND FOG WIND 140 DEG 14 KTS GUSTS... VR3L 3 HUNDRD OVRCST VIS 1 MILE RAIN AND FOG

In addition to the above official weather bureau forecast, the watch supervisor conferred with airline company forecasters to obtain their opinion of the weather. All agreed that the weather would be as bad as forecasted or intermittently worse, particularly visibility.

Based on the above forecasts and runway configurations, the demand would exceed the acceptance rate LGA and JFK. The possibility of visibility dropping below one mile existed. This could cause alternating approach at LGA and JFK and a reduction in acceptance rates. At 1300Z the watch supervisor called for New York AFCP to be implemented for 051800Z to 060400Z based on (revised) acceptance rates of 28 for JFK and 20 for LGA, as transmitted to CFCF. He advised ARINC and the Central Flow Control Facility (CFCF) at Washington, D.C. of his decision. Since the Kansas City computer was out of service, the manual system was employed. All zone III centers were advised of AFCP implementation via the CFCF and of the computer outage so as to give them as much time as possible to prepare.

The weather situation from Maine to Georgia was poor. All busy terminals, Boston, Washington National, Philadelphia, Baltimore were experiencing large arrival and departure delays. The following is a sample of the type of message the CFCF was putting out to keep the aviation community advised.

1743Z ATTN FLOW CONTROLLERS
CFCF FLOW CONTROL ADVISORY NO. 6 VOID 052200Z

NOON REPORT /EST/ ON ATC SYSTEM STATUS.

BOS AIRPORT CLOSED FOR PLOWING UNTIL 1700Z.

PHL BELOW LANDING MINIMUMS. EXPECTED TO REMAIN THIS WAY UNTIL 0000Z . 6 AIRCRAFT HOLDING.

ZAU CANCELLED THEIR QUOTAS AT 1710Z.
30 AIRCRAFT ARE HOLDING OVER ORD WITH AN AVERAGE OF 30/40 MINUTES DELAY.

ZFW' ZHU AND ZAB EXPECT MODERATE TO HEAVY MILITARY TRAFFIC AFTER 1800Z.

PDX BELOW LANDING MINIMUMS EXPECTED TO IMPROVE BY 1730Z.
10 AIRCRAFT HOLDING.

ZNY HAS IMPLEMENTED AFCPS WHICH WILL RESULT IN DEPARTURE DELAYS TO TRAFFIC C ENROUTE TO JFK OR LGA.

TRAFFIC THROUGHOUT THE SYSTEM IS MODERATE TO HEAVY.

At 1800Z, the start time of AFCP, the New York Terminal Area had ceilings of 200 - 300 feet overcast, visibility 1/2 to 1 mile with rain and fog. Intermittently one or the other airport would go below minimums. The ceiling and visibility for JFK, obtained from the CATER record, are plotted in Figure 9.

- At 1800Z to 1810Z JFK was below landing minimums.
- At 1859Z JFK ILS went out of service; JFK below landing minimums.
- At 1906Z JFK ILS resumed operation.
- At 1922Z JFK ILS R/W 22 failed again. Approaches stopped.
- At 1949Z JFK ILS R/W 22 resumed operation. Approaches commenced. Arrival delays into JFK not at 60 minutes.

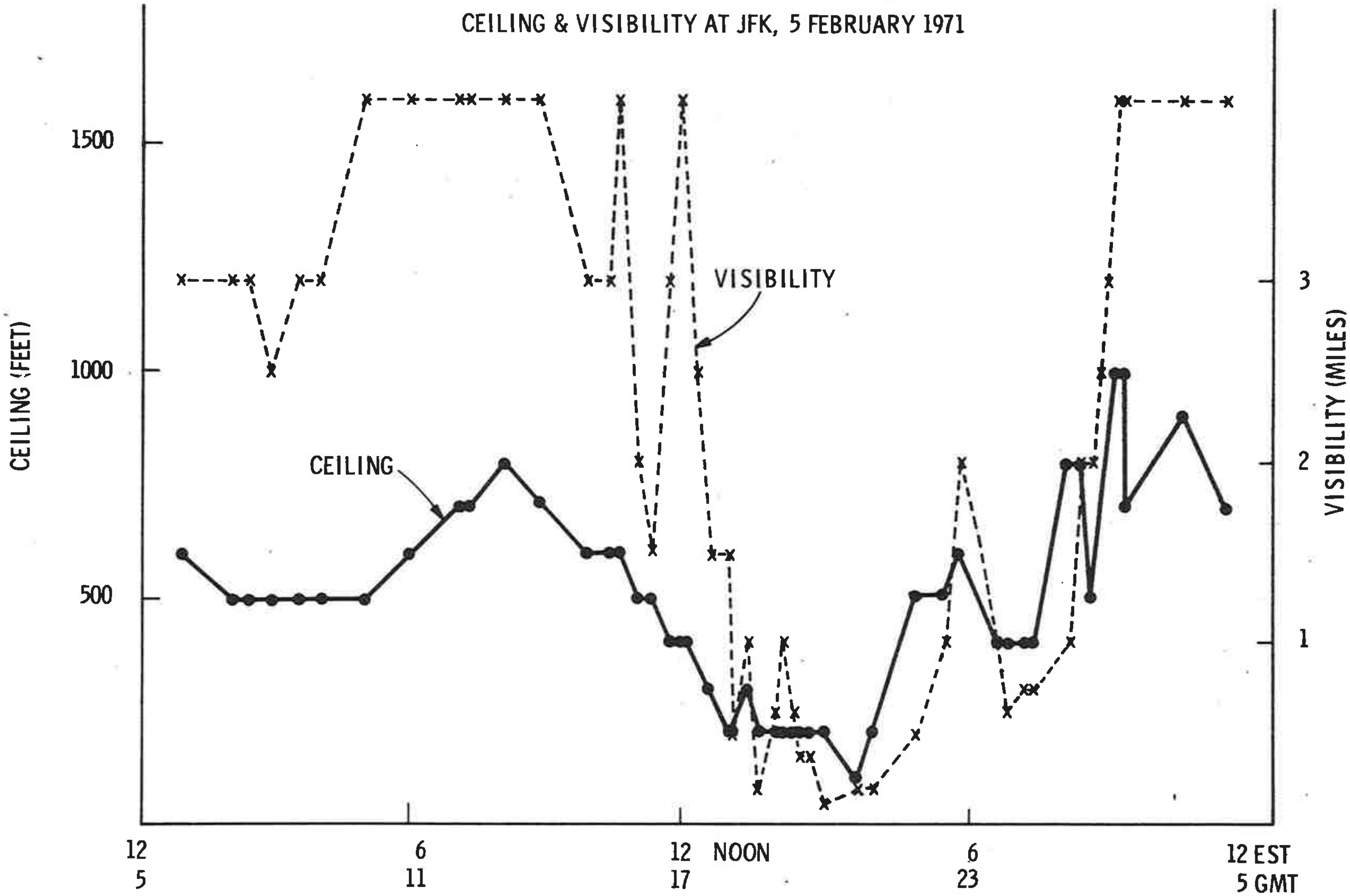

Figure 9. Ceiling & Visibility at JFK, 5 February 1971

At 1956Z approaches to JFK were discontinued on account of weather. During the 2000 hour JFK had 6 landings, 8 take-offs, and 6 missed approaches; during the 2100 hour zero landings, 13 take-offs and no missed approaches.

The following CFCF advisory is self-explanatory:

2208 CFC ADVISORY
AIRLINE DISPATCHERS/U.S. CNTRS. INFO OTHERS.
CFCF FLOW CONTROL ADVISORY NO.11 VOID 060100.
REACH OF DELAY SITUATION AT 2120. NO APPROACHES BEING MADE AT JFK/EWR/LGA DUE TO WX CONDITIONS. BOS ARRIVAL DELAYS 30 MINUTES. ORD 20 MINUTE ARRIVAL DELAYS. DCA 15 TO 20 MINUTE ARRIVAL AND DEPARTURE DELAYS. PHL 30 MINUTE ARRIVAL DELAYS. AT 2130 JFK HAS DEP MINIMUMS BUT DEP DELAYS ON 7 AIRCRAFT RUNNING ONE HOUR AND 15 MINUTES.
JFK ARRIVAL DELAYS EXPECTED TO REMAIN 60 TO 70 MINUTES THROUGH 2300. ARRIVAL DELAYS AT EWR/LGA EXPECTED TO BE ABOUT 30/40 MINUTES THROUGH 2330. ORD DELAYS MAY REACH 30 MINUTES ACCT VOLUME BY 2330. AT 2130 ORD ACCEPTANCE RATE 50 TO 55 PER HOUR.

2212Z## FOR THE 2100 TO 2200 PERIOD NOACFT LANDED JFK. JFK ADVISES THERE WERE 17 DIVERSIONS TO OTHER ARPTS. 27 ARVD AT LGA AND 16 AT EWR

From 2200Z to 060400Z the forecasters predicted that the ceilings and visibilities would stabilize at 400 to 600 feet, and one to two miles and it did for the remainder of the evening. However, the damage had been done. Traffic was being held at all fixes and delays to some aircraft were over ninety minutes. From 1900Z to 2200Z some sixty odd flights diverted. For the remainder of the evening with all landing aids operative, Kennedy, LaGuardia and Newark had a steady flow of arrivals so that AFCP for LGA was cancelled at 2330Z and JFK at 060030Z.

AFCP Ground Holds - Allocations

Based on a landing capacity of 28 for JFK and 20 for LGA, allocations for the AFCP period were sent to each center by NYARTCC. These allocations were made up and sent out from 1339Z to 1436Z. They are given in Schedule A, reproduced from the original center B teletype message. No allocations for LGA were assigned to zone III. Oakland ARTCC was advised to call New York Center flow controller for allocations.

SCHEDULE A: Original AFCP Allocations, Issued on Center B

CNTRS ZONE 1 ZBW ZDC ZJX ZOB ZAU ZTL ZNY CYUL, CYYZZR ZID

ADV FLOW CTL RSTNS FOR ACFT ARRG JFK AFT Ø51759Z
VOID AT Ø5Ø359Z

HR	BW	NY	DC	JX	OB	AU	TL	ID	YZ	UL	MGD
18	2	Ø	2	Ø	Ø	1	1	1	1	1	Ø45
19	2	Ø	1	Ø	1	1	Ø	Ø	Ø	Ø	Ø45
2Ø	2	1	1	Ø	1	1	Ø	Ø	Ø	Ø	Ø45
21	2	1	1	Ø	1	1	Ø	Ø	1	1	Ø45
22	2	1	1	Ø	1	1	1	Ø	Ø	1	Ø45
23	2	1	1	Ø	2	1	Ø	Ø	1	1	Ø45
ØØ	2	1	Ø	Ø	2	1	Ø	Ø	Ø	1	Ø45
Ø1	2	1	1	1	2	Ø	1	1	1	Ø	Ø45
Ø2	2	1	1	Ø	2	Ø	Ø	Ø	Ø	Ø	Ø45
Ø3	2	1	1	Ø	2	2	2	Ø	1	1	Ø45

ZNY Ø51429Z

CNTRS ZONE II ZMA ZHU ZFW ZME ZKC ZMP ZDV

ADV FLOW CONTROL RSTNS FOR AFCT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	MA	HU	FW	ME	KC	MP	DV	MGD
18	2	Ø	Ø	Ø	Ø	Ø	1	Ø45
19	2	Ø	Ø	Ø	1	Ø	Ø	Ø45
2Ø	3	1	1	Ø	Ø	Ø	Ø	1ØØ
21	3	2	Ø	Ø	Ø	Ø	1	1ØØ
22	3	Ø	Ø	Ø	Ø	1	Ø	1ØØ
23	3	Ø	Ø	Ø	Ø	1	1	1ØØ
ØØ	3	Ø	2	Ø	Ø	Ø	1	Ø45
Ø1	3	1	Ø	1	Ø	Ø	Ø	Ø45
Ø2	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
Ø3	3	1	2	1	Ø	Ø	1	Ø45

ZNY Ø514Ø47

SCHEDULE A: Original AFCP Allocations, Issued on Center B

CNTRS ZONE III ZAB ZLA ZLC ZSE ZOA ZGT
ADVN FLOW CTL RSTNS FOR ACFT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	AB	LA	LC	SE	OA	GT	MGD
18	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
19	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
2Ø	1	2	1	Ø	Ø	Ø	Ø45
21	1	2	Ø	1	1	Ø	Ø45
22	Ø	2	Ø	1	2	Ø	Ø45
23	Ø	2	Ø	Ø	2	Ø	Ø45
ØØ	Ø	2	Ø	Ø	2	Ø	Ø45
Ø1	Ø	2	1	1	Ø	Ø	Ø45
Ø2	1	2	Ø	Ø	2	Ø	Ø45
Ø3	Ø	3	Ø	Ø	2	Ø	Ø45

ZNY Ø51339Z

CNTRS ZONE IV ZBW ZDC

ADV FLOW CTL RSTNS FOR ACFT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	BW	NY	DC	MGS
18	8	3	Ø	Ø45
19	3	4	Ø	Ø45
2Ø	6	3	Ø	Ø45
21	8	2	1	Ø45
22	5	5	1	Ø45
23	3	5	1	Ø45
ØØ	3	2	Ø	Ø45
Ø1	2	3	Ø	Ø45
Ø2	1	4	1	Ø45
Ø3	1	3	1	Ø45

ZNY Ø51416Z

SCHEDULE A: Original AFCP Allocations, Issued on Center B

CNTRS ZONE I ZBW ZDC ZJX ZOB ZAU ZTL ZNY CYUL CYYZZR ZID
ADV FLOW CTL RSTNS FOR ACFT ARRG LGA AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	BW	NY	DC	JX	OB	AU	TL	ID	YZ	UL	MGD
18	4	1	3	Ø	3	3	2	4	Ø	1	Ø45
19	3	1	4	1	4	3	1	2	1	Ø	Ø45
2Ø	2	1	4	1	3	4	1	Ø	1	Ø	Ø45
21	3	1	4	Ø	3	4	1	3	Ø	Ø	Ø45
22	3	1	4	1	3	4	1	2	1	1	Ø45
23	3	1	4	1	3	3	1	2	Ø	1	Ø45
ØØ	3	1	5	Ø	3	3	1	2	1	Ø	Ø45
Ø1	3	1	4	Ø	3	3	1	2	Ø	1	Ø45
Ø2	3	1	4	Ø	2	4	1	2	1	1	Ø45
Ø3	1	1	2	Ø	2	3	1	2	Ø	1	Ø45

ZNY Ø5141ØZ

CNTRS ZONE II ZMA ZHU ZFW ZME ZKC ZMP ZDV

ZDV FLOW CONTROL RSTNS FOR AFCT ARRG LGA AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	MA	HU	FW	ME	KC	MP	DV	MGD
18	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
19	1	Ø	Ø	1	Ø	1	Ø	Ø45
2Ø	Ø	Ø	1	Ø	3	Ø	Ø	Ø45
21	3	Ø	1	Ø	1	Ø	Ø	Ø45
22	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
23	2	Ø	Ø	Ø	2	Ø	Ø	Ø45
ØØ	1	Ø	Ø	Ø	1	Ø	Ø	Ø45
Ø1	Ø	1	Ø	1	Ø	1	Ø	Ø45
Ø2	1	1	Ø	Ø	1	1	Ø	Ø45
Ø3	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø45

ZNY Ø51436Z

AFCP regulations permit the swapping of allocations within a zone. The concerned center contacts its lead center and if the action will not exceed the hourly zone allocation, the lead center can authorize a change. They are required, however, to notify NYARTCC. They must also notify New York of any deletions as soon as practical, as well as any requests for additional allocations. These actions did occur on February 5, and an attempt was made by the TSC investigators to reconstruct them, The reconstruction was done by inspecting all written records of swappings and applying them to the original allocations shown above. The results were as shown in Schedule B, based on the original allocation message. No zone III or IV allocations are issued for LGA. Concerned centers in zone III could obtain allocations by calling lead centers who in turn would call NYARTCC flow controllers.

The initial and modified allocations for the AFCP hours are plotted in Figure 10. It is of interest to compare them with the scheduled arrivals (excluding cancellations) and with the available arrivals during the same hours. This is done in Table 5. It can be seen from that table that the modified allocations were well above the arrivals on the average, for both airports. It will be seen from the simulation results, however, that if these (modified) allocations are strictly applied on a center-by-center basis the net arrivals in most hours are less than actually occurred. How this can occur is obvious from Schedule C. This is a tally of the modified allocations and the actual arrivals by hour and by center of origin. While the allocations were greater than the arrivals for most centers, they were less than arrivals in a few cases. Strict enforcement would have reduced arrivals in those few cases, but, because of lack of demand, would not have increased arrivals in the other cases. Thus, strict enforcement of the allocations would have yielded, in the net, fewer arrivals during the AFCP hours than actually occurred.

The conclusion to be drawn from this analysis is simply that adjusting allocations (in proportion to demand but within the estimated capacity) is an extensive intercenter coordination task that apparently was not carried out effectively on February 5.

Acceptance Rate Estimates

One source of acceptance rate estimates is the NYARTCC log for February 5, 1971, which also recorded the original allocations as well as the CIFRR count of actual arrivals. Secondly, the CATER records for JFK were secured and, after removal of helicopter operations and missed approaches, were tabulated. All of the data for 5 February acceptance rates for the AFCP period are summarized in Table 6, along with the allocations and modified allocations. Figure 11 shows the NYARTCC estimates of acceptance rates, the tower counts of actual arrivals, and the arrivals given in the flight strip data.

SCHEDULE B: Modified AFCP Allocations, Reconstructed from Available Swapping Records

CNTRS ZONE 1 ZBW ZDC ZJX ZOB ZAU ZTL ZNY CYUL CYYZZR ZID

ADV FLOW CTL RSTNS FOR ACFT ARRG JFK AFT 051759Z
VOID AT 060359Z

HR	BW	NY	DC	JX	OB	AU	TL	ID	YZ	UL	MGD
18	2	Ø	2	Ø	~~Ø~~1	1	1	1	1	1	Ø45
19	2	Ø	1	Ø	~~1~~0	1	Ø	Ø	Ø	Ø	Ø45
20	~~2~~4	1	1	Ø	~~1~~~~0~~1	1	Ø	Ø	Ø	Ø	Ø45
21	~~2~~4	1	1	Ø	1	1	Ø	Ø	1	1	Ø45
22	2	1	~~1~~3	Ø	~~1~~3	1	1	Ø	Ø	1	Ø45
23	2	1	~~1~~4	Ø	~~2~~6	1	Ø	Ø	1	1	Ø45
ØØ	2	1	Ø	Ø	2	1	Ø	Ø	Ø	1	Ø45
Ø1	2	1	1	~~1~~0	~~2~~6	Ø	~~1~~2	1	1	Ø	Ø45
Ø2	2	1	1	Ø	2	Ø	Ø	Ø	Ø	Ø	Ø45
Ø3	2	1	1	Ø	2	2	2	Ø	1	1	Ø45

ZNY Ø51429Z

CNTRS ZONE II ZMA ZHU ZFW ZME ZKC ZMP ZDV

ADV FLOW CONTROL RSTNS FOR AFCT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	MA	HU	FW	ME	KC	MP	DV	MGD
18	2	Ø	Ø	Ø	Ø	Ø	~~1~~2	Ø45
19	2	Ø	Ø	Ø	1	Ø	Ø	Ø45
2Ø	~~3~~4	1	1	Ø	Ø	Ø	Ø	1ØØ
21	~~3~~~~4~~3	2	Ø	Ø	Ø	Ø	~~1~~0	1ØØ
22	3	Ø	Ø	Ø	Ø	1	~~Ø~~1	1ØØ
23	~~3~~4	Ø	~~Ø~~1	Ø	Ø	1	1	1ØØ
ØØ	3	~~Ø~~2	~~2~~3	Ø	~~Ø~~1	Ø	1	Ø45
Ø1	3	~~1~~2	Ø	1	~~Ø~~1	Ø	Ø	Ø45
Ø2	3	~~Ø~~1	Ø	Ø	Ø	Ø	Ø	Ø45
Ø3	3	1	2	1	Ø	Ø	1	Ø45

ZNY Ø514Ø4Z

SCHEDULE B: Modified AFCP Allocations, Reconstructed from Available Swapping Records

CNTRS ZONE III ZAB ZLA ZLC ZSE ZOA ZGT
ADVN FLOW CTL RSTNS FOR ACFT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	AB	LA	LC	SE	OA	GT	MGD
18	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
19	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
2Ø	~~1~~2	2	1	Ø	Ø	Ø	Ø45
21	1	2	Ø	~~1~~2	1	Ø	Ø45
22	Ø	2	Ø	1	2	Ø	Ø45
23	Ø	2	Ø	Ø	~~2~~1	Ø	Ø45
ØØ	Ø	2	Ø	Ø	2	Ø	Ø45
Ø1	Ø	2	1	1	Ø	Ø	Ø45
Ø2	1	2	Ø	Ø	2	Ø	Ø45
Ø3	Ø	3	Ø	Ø	2	Ø	Ø45

ZNY Ø51339Z

ADV FLOW CTL RSTNS FOR ACFT ARRG JFK AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	BW	NY	DC	MGS
18	8	3	Ø	Ø45
19	~~7~~6	~~4~~6	Ø	Ø45
2Ø	~~6~~8	3	Ø	Ø45
21	~~8~~10	2	1	Ø45
22	5	~~5~~6	1	Ø45
23	3	5	1	Ø45
ØØ	3	2	Ø	Ø45
Ø1	2	3	Ø	Ø45
Ø2	1	4	1	Ø45
Ø3	1	3	1	Ø45

ZNY Ø51416Z

SCHEDULE B: Modified AFCP Allocations, Reconstructed from Available Swapping Records

CNTRS ZONE 1 ZBW ZDC ZJX ZOB ZAU ZTL ZNY CYUL CYYZZR ZID
ADV FLOW CTL RSTNS FOR ACFT ARRG LGA AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	BW	NY	DC	JX	OB	AU	TL	ID	YZ	UL	MGD
18	4	1	~~3~~4	Ø	3	3	~~2~~3	~~1~~1	Ø	1	Ø45
19	3	~~1~~2	~~4~~5	1	~~4~~3	~~3~~4	~~1~~2	2	1	Ø	Ø45
2Ø	~~2~~4	1	~~4~~5	~~1~~0	~~3~~4	~~4~~6	~~1~~2	~~Ø~~1	1	Ø	Ø45
21	~~3~~2	~~1~~5	~~4~~8	Ø	~~3~~4	4	~~1~~3	~~3~~4	Ø	Ø	Ø45
22	~~3~~6	1	~~4~~6	~~1~~0	3	4	1	2	1	1	Ø45
23	3	1	4	1	~~3~~5	3	1	2	Ø	1	Ø45
ØØ	3	1	5	Ø	3	~~3~~2	1	2	1	Ø	Ø45
Ø1	3	1	4	Ø	3	~~3~~2	1	2	Ø	1	Ø45
Ø2	3	1	4	Ø	2	4	1	2	1	1	Ø45
Ø3	1	1	2	Ø	2	3	1	2	Ø	1	Ø45

ZNY Ø5141ØZ

CNTRS ZONE II ZMA ZHU ZFW ZME ZKC ZMP ZDV

ZDV FLOW CONTROL RSTNS FOR AFCT ARRG LGA AFT Ø51759Z
VOID AT Ø6Ø359Z

HR	MA	HU	FW	ME	KC	MP	DV	MGD
18	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø45
19	1	Ø	Ø	1	Ø	1	Ø	Ø45
2Ø	~~Ø~~1	Ø	~~1~~0	Ø	3	Ø	Ø	Ø45
21	3	Ø	1	Ø	1	Ø	Ø	Ø45
22	Ø	Ø	~~Ø~~1	Ø	Ø	Ø	Ø	Ø45
23	2	Ø	~~Ø~~2	Ø	2	Ø	Ø	Ø45
ØØ	1	Ø	~~Ø~~1	Ø	1	Ø	Ø	Ø45
Ø1	Ø	1	Ø	1	~~Ø~~1	1	Ø	Ø45
Ø2	1	1	Ø	Ø	1	1	Ø	Ø45
Ø3	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø45

ZNY Ø51436Z

TABLE 5

ARRIVALS & ALLOCATIONS FOR AFCP HOURS

JFK

	SCHED.** ARRIVALS	SCHED.*** ARRIVALS	INITIAL ALLOCATIONS	MODIFIED ALLOCATIONS	AVAILABLE ARRIVALS*	ACTUAL ARRIVALS
1800	28	22	23	24	13	11
1900	26	22	15	19	18	1
2000	37	29	24	30	27	6
2100	39	30	30	34	26	0
2200	40	29	28	34	25	19
2300	34	29	27	36	23	30
2400	27	24	22	26	29	28
0100	33	24	24	30	28	29
0200	27	22	20	21	22	31
0300	26	18	30	30	19	26
MEAN	31.9	24.9	24.3	28.4	23.0	18.1

LGA

	SCHED.** ARRIVALS	SCHED.*** ARRIVALS	INITIAL ALLOCATIONS	MODIFIED ALLOCATIONS	AVAILABLE ARRIVALS*	ACTUAL ARRIVALS
1800	26	20	21	20	15	15
1900	26	21	23	26	19	17
2000	27	23	21	28	19	21
2100	31	26	24	34	34	25
2200	31	24	21	26	11	11
2300	25	21	23	27	27	31
2400	22	20	21	21	29	25
0100	33	25	21	21	19	16
0200	24	22	23	24	26	36
0300	18	13	14	14	12	13
MEAN	26.3	21.5	21.2	24.1	21.1	21.0

*SEE FOOTNOTE ON PAGE 24

**INCLUDING OAG FLIGHTS THAT DID NOT REACH ZNY ON FEBRUARY 5

***EXCLUDING OAG FLIGHTS THAT DID NOT REACH ZNY ON FEBRUARY 5

TABLE 6

HOURLY ACCEPTANCE RATE ESTIMATES FOR JFK AND LGA
5 FEB 1800Z TO 6 FEB 0300Z

Time of Issuance		Source of Estimate or Data									
1151Z	:	Facility Status and Runway Configuration Report, Acceptance Rates									
		1800Z									0300Z
JFK	:	28	28	28	28	28	28	28	28	28	28
LGA	:	25	25	25	25	25	25	25	25	25	25
about 1300Z	:	Acceptance Rates, Estimated by NYARTCC, Fig. 8C									
		1800Z									0300Z
JFK	:	28	28	28	28	28	28	28	28	28	28
LGA	:	20	20	20	20	20	20	20	20	20	20
1339Z-1436Z	:	Initial Allocations (issued on teletype) Fig. 8B									
		1800Z									0300Z
JFK	:	23	15	24	30	28	27	22	24	20	30
LGA	:	21	23	21	24	21	23	21	21	23	14
1500Z-2330Z	:	Modified Allocations (as issued on teletype, plus available swapping records) Fig. 8B									
		1800Z									0300Z
JFK	:	24	19	30	34	34	36	26	30	21	30
LGA	:	20	26	28	34	26	27	21	21	24	14
5 FEB entry	:	Allocations (from NYARTCC log)									
		1800Z									0300Z
JFK	:	25	25	25	25	25	25	25	25	25	25
LGA	:	20	20	20	20	20	20	20	20	20	20
5 FEB entry	:	Modified Allocations (from NYARTCC log)									
		1800Z									0300Z
JFK	:	21	29	32	30	29	32	29	27	24	—
LGA	:	18	22	28	19	27	26	26	25	21	—

TABLE 6 (cont.)

Time of Issuance		Source of Estimate or Data									
5 FEB entry	:	Actual acceptance rates (NYARTCC log of tower counts) Fig. 8C									
		1800Z									0300Z
JFK	:	14	7	18	0	23	33	28	34	34	—
LGA	:	15	18	28	27	19	32	25	22	36	—
5 FEB	:	CATER data, acceptance rates									
		1800Z									0300Z
JFK	:	10	1	6	0	22	30	28	31	32	31
LGA	:	- not available for LGA on February 5 -									
5 FEB	:	Flight Strip Data, acceptance rates, Fig. 8C									
JFK	:	11	1	6	0	19	30	28	29	31	26
LGA	:	15	27	21	25	11	31	23	14	31	7
5 FEB	:	Runways in Use (CATER data and NYARTCC log)									
JFK	:	4/22	22	22	22	22	22	22	22	22	22
LGA	:	4	4	4	4	4/22	—	—	—	—	—

	Averages: 1800Z through 0300Z	JFK	LGA
1151Z	Facility Status and Runway Report	28	25
1300Z	NYARTCC Estimates	28	20
1400Z	Initial Allocations (Center B)	24.3	21.2
	Modified Allocations (Center B & Swaps)	28.4	24.1
	Initial Allocations (NYARTCC log)	25	20
	Modified Allocations (NYARTCC log)	28.1	23.6
	Actual, tower counts	21.2	24.7
	Actual, CATER	19.1	—
	Actual, Flight Strip Data	18.1	20.5

SCHEDULE C - 1

MODIFIED ALLOCATIONS AND ACTUAL ARRIVALS
AT JFK BY HOUR AND BY CENTER OF ORIGIN

Originating Center	GMT Hour 1800	1900	2000	2100	2200	2300	2400	Totals	
ZBW	2	2	4	4	2	2	2	18	Allocated
	3	1	0	0	3	2	3	12	Used
	-1	1	4	4	-1	0	-1	6	Surplus
ZBW/O	8	3	8	10	5	3	3	40	
	1	5	5	10	4	3	0	28	
	7	-2	3	0	1	0	3	12	
ZNY	0	2	1	1	1	1	1	7	
	0	1	3	1	0	0	2	7	
	0	1	-2	0	1	1	-1	0	
ZNY/O	3	4	3	2	5	5	2	22	
	0	2	1	2	4	3	3	15	
	3	2	2	0	1	2	-1	7	
ZDC	2	1	1	1	2	0	0	7	
	1	2	2	2	2	4	3	16	
	1	-1	-1	-1	0	-4	-3	-9	
ZDC/O	0	0	0	1	1	1	0	3	
	0	0	1	0	4	0	0	5	
	0	0	-1	1	-3	1	0	-2	
ZJX	0	0	0	0	0	0	0	0	
	0	0	1	0	0	0	0	1	
	0	0	-1	0	0	0	0	-1	
ZOB	1	0	1	3	2	3	2	12	
	0	3	1	0	3	2	2	11	
	1	-3	0	3	-1	1	0	1	
ZAU	1	1	1	1	2	1	1	8	
	0	3	1	0	2	2	1	9	
	1	-2	0	1	0	-1	0	-1	
ZTL	1	0	0	2	2	1	0	7	
	0	1	0	0	1	1	0	3	
	1	-1	0	2	1	0	0	4	
ZYZ	1	0	0	1	0	1	0	3	
	1	0	0	1	0	0	0	2	
	0	0	0	0	0	1	0	1	

SCHEDULE C - 1 (cont.)

Originating Center	1800	1900	2000	2100	2200	2300	2400	Totals	
				GMT Hour					
ZUL	1	0	0	1	1	1	1	5	Allocated
	0	0	0	0	0	0	1	1	Used
	1	0	0	1	1	1	0	4	Surplus
ZMA	2	2	7	4	3	4	5	27	
	2	2	3	4	3	3	4	21	
	0	0	4	0	0	1	1	6	
ZHU	0	0	1	1	0	0	1	3	
	1	0	0	1	1	0	0	3	
	-1	0	1	0	-1	0	1	0	
ZFW	0	0	1	0	0	1	3	5	
	0	0	0	1	0	0	1	2	
	0	0	1	-1	0	1	2	3	
ZME	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	
ZKC	0	1	0	0	0	0	0	1	
	0	0	0	0	1	0	0	1	
	0	1	0	0	-1	0	0	0	
ZMP	0	0	0	0	1	1	0	2	
	0	0	0	0	1	1	0	2	
	0	0	0	0	0	0	0	0	
ZDV	2	0	0	0	1	1	1	5	
	1	0	1	0	1	1	0	4	
	1	0	-1	0	0	0	1	1	
ZAB	0	0	1	1	0	0	0	2	
	0	0	2	0	0	0	0	2	
	0	0	-1	1	0	0	0	0	
ZLC	0	0	1	0	0	1	0	2	
	0	0	0	1	0	0	1	2	
	0	0	1	-1	0	1	-1	0	
ZLA	0	0	2	2	2	2	2	10	
	0	0	0	2	4	3	1	10	
	0	0	2	0	-2	-1	1	0	
ZSC	0	0	0	2	1	0	0	3	
	0	0	0	0	2	0	0	2	
	0	0	0	2	-1	0	0	1	

SCHEDULE C - 1 (cont.)

Originating Center	GMT Hour 1800	1900	2000	2100	2200	2300	2400	Totals	
ZOA	0	0	0	1	2	2	2	7	
	0	0	0	0	2	1	2	5	
	0	0	0	1	0	1	0	2	
ZGT	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	
ALL	24	16	31	38	33	31	26	199	Allocated
	10	20	21	25	38	26	24	164	Used
	14	-4	10	13	-5	5	2	35	Surplus

SCHEDULE C - 2

MODIFIED ALLOCATIONS AND ACTUAL ARRIVALS AT LGA BY HOUR AND BY CENTER OF ORIGIN

Originating Center	GMT Hour 1800	1900	2000	2100	2200	2300	2400	Totals	
ZBW	4	3	4	7	5	3	3	29	Allocated
	3	1	4	5	3	3	0	19	Used
	1	2	0	2	2	0	3	10	Surplus
ZNY	1	2	1	1	1	1	1	8	
	1	0	3	1	0	3	1	9	
	0	2	-2	0	1	-2	0	-1	
ZDC	4	5	5	8	8	4	5	39	
	2	4	3	6	3	6	6	30	
	2	1	2	2	5	-2	-1	9	
ZJX	0	1	0	0	0	1	0	2	
	0	0	2	0	0	2	0	4	
	0	1	-2	0	0	-1	0	-2	
ZOB	3	3	4	4	4	3	3	24	
	2	4	2	5	2	4	7	26	
	1	-1	2	-1	2	-1	-4	-2	
ZAU	3	4	6	4	4	3	3	27	
	1	0	3	2	5	4	4	19	
	2	4	3	2	-1	-1	-1	8	
ZTL	3	2	2	1	1	1	1	11	
	1	3	0	0	1	0	2	7	
	2	-1	2	1	0	1	-1	4	
ZID	1	2	1	4	4	2	2	16	
	2	2	1	4	0	2	4	15	
	-1	0	0	0	4	0	-2	1	
ZYZ	0	1	1	0	0	0	1	3	
	0	1	1	0	1	0	0	3	
	0	0	0	0	-1	0	1	0	
ZUL	1	0	0	0	0	1	0	2	
	0	1	0	0	0	0	1	2	
	1	-1	0	0	0	1	-1	0	
ZMA	0	1	0	0	0	2	1	4	
	1	0	1	3	0	2	0	7	
	-1	1	-1	-3	0	0	1	-3	

SCHEDULE C - 2 (cont.)

Originating Center	1800	1900	2000	2100	2200	2300	2400	Totals	
				GMT Hour					
ZHU	0	0	0	0	0	0	0	0	Allocated
	0	0	0	0	0	0	0	0	Used
	0	0	0	0	0	0	0	0	Surplus
ZFW	0	0	0	0	1	1	1	3	
	1	0	0	1	0	0	1	3	
	-1	0	0	-1	1	1	0	0	
ZME	0	1	0	0	0	0	0	1	
	1	1	0	0	0	0	0	2	
	-1	0	0	0	0	0	0	-1	
ZKC	0	0	3	3	0	2	1	9	
	0	0	3	1	0	0	2	6	
	0	0	0	2	0	2	-1	3	
ZMP	0	1	0	0	0	0	0	1	
	0	1	0	0	0	0	0	1	
	0	0	0	0	0	0	0	0	
ZDV	0	1	0	0	0	0	0	1	
	0	0	0	0	0	0	0	0	
	0	1	0	0	0	0	0	1	
ALL	20	27	27	32	28	24	22	180	Allocated
	15	18	23	28	15	26	28	153	Used
	5	9	4	4	13	-2	-6	27	Surplus

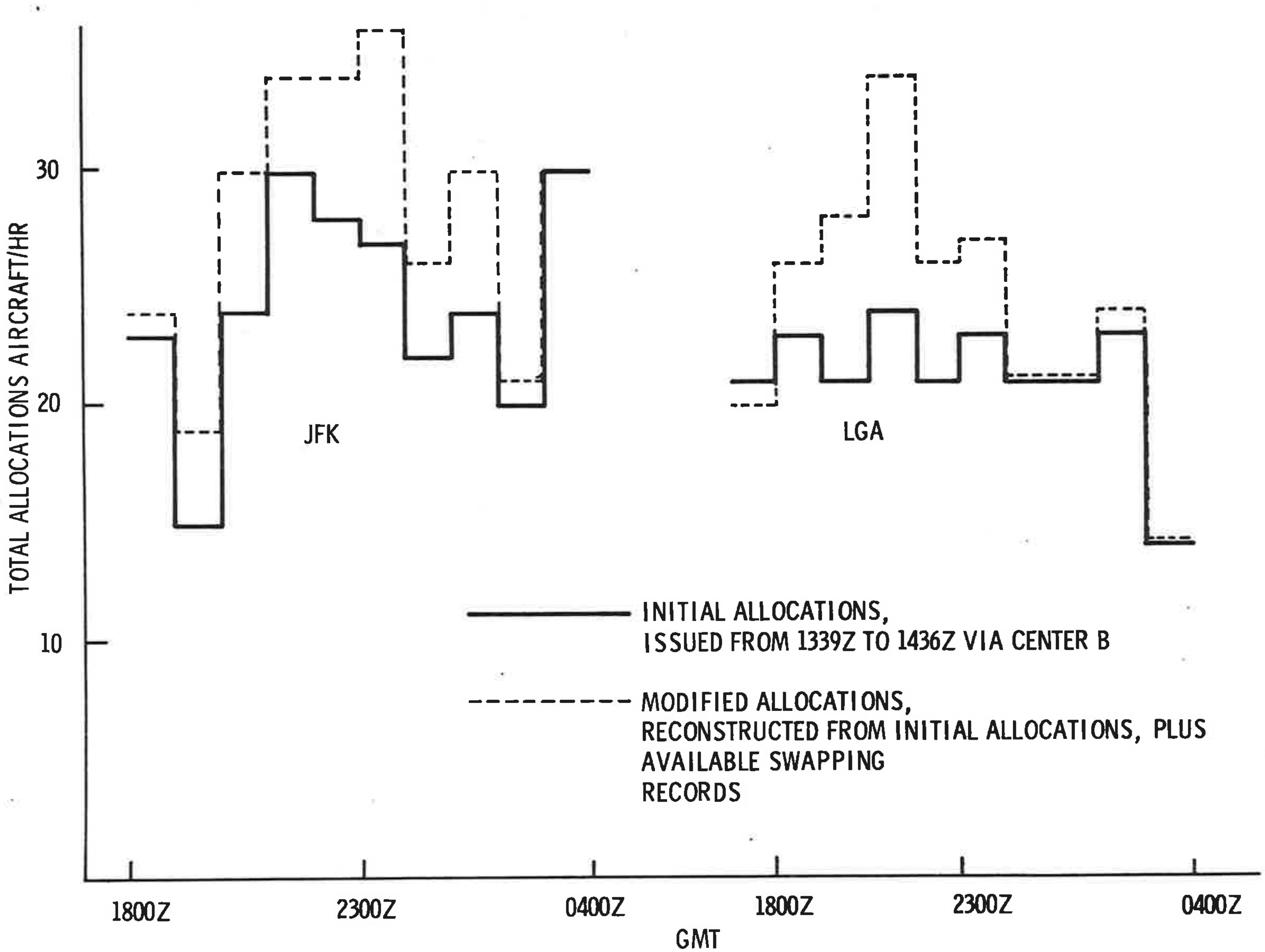

Figure 10. Initial & Modified Allocations

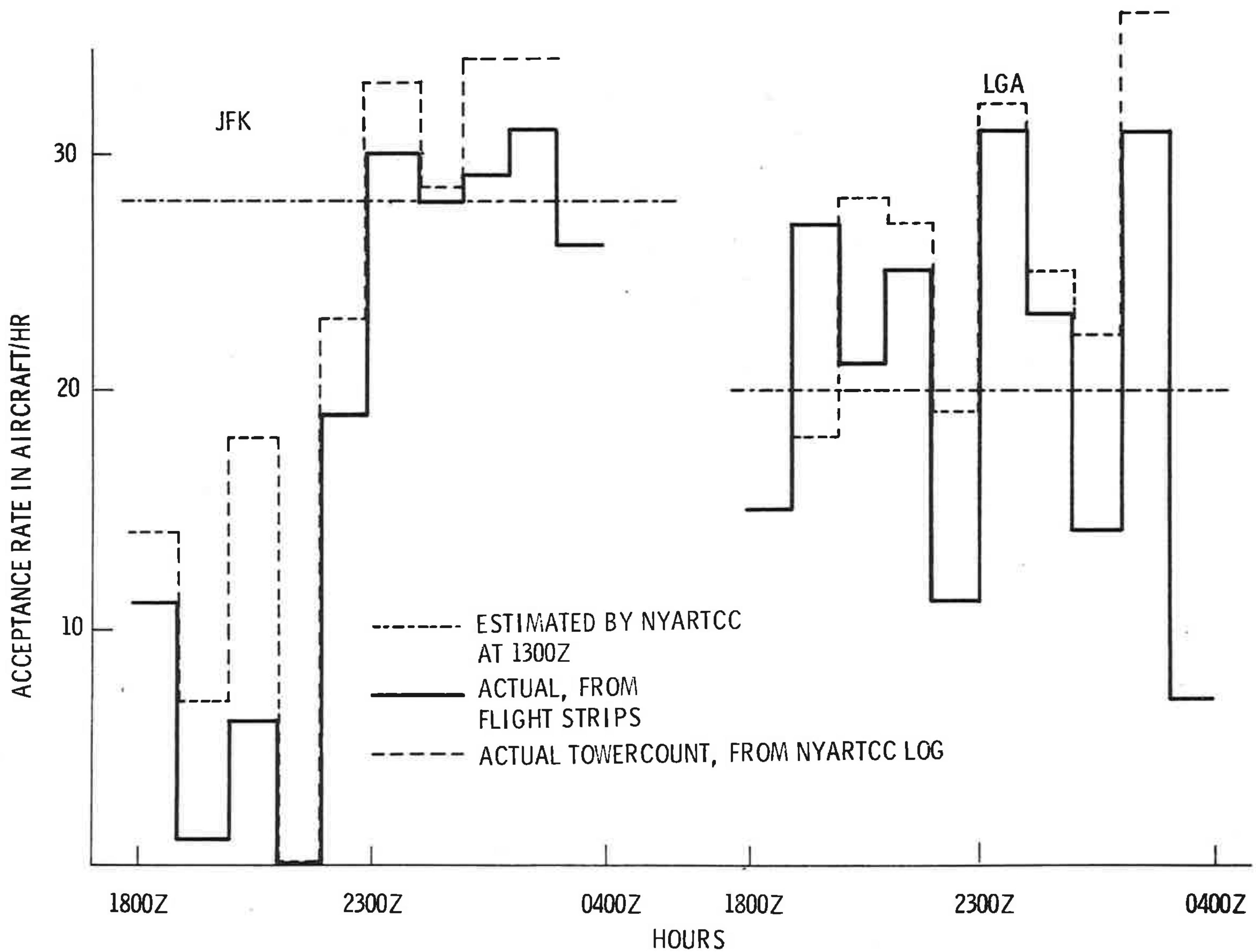

Figure 11. 5 Feb. 1971: Estimated & Actual Acceptance Rates

Since both airports were in saturation during the AFCP hours (with the possible exception of LGA at 1800Z and 1900Z), the actual landings are good approximations to the landing capacity. With that in mind, several observations are made readily from Table 6 and Figure 11.

1. The NYARTCC estimate of 28/hour for JFK was far above the actual capacity from 1800Z to 2200Z, but close to it from 2300Z to 0300Z. The estimate for LGA was very close to the average actual capacity, but the actual fluctuated over a large range.
2. The actual landing capacity at JFK (Figure 11) is strongly correlated with the visibility and ceiling at JFK (Figure 9).
3. The flight strip data agreed well with the CATER data, but the tower counts were higher, on the average, by about 14% for JFK and about 20% for LGA. This may be due to tower-to-tower flights.
4. The allocations do not agree with the landing capacity estimates. It is possible that the landing capacities were re-estimated, but not recorded, and that the allocations were made from the new estimates. The wide variations in the allocations, however, seem to indicate that they were made (erroneously) on the basis of the demand rather than on the basis of the capacity.

It might be well to point out at this time that there is and will be discrepancies in and between collected statistics. It is believed that some of the swapping and reallocations were verbal and not recorded. Again, data collected by one agency because of its parochial function may not agree with the next level of control. A good example is diversions. The CIFRR reported fewer diversions than the New York Center. The reason is that they reported only those under their control, whereas the Center reported all diversions in ZNY.

Diversions

During the 24 hour period of February 5, 1971, there were sixty-six diverted flights indicated in the flight strips. Fifty-eight were destined for JFK and eight for LGA. Sixty-one of the diversions occurred during AFCP hours; five diversions, of which three were for LGA and two for JFK, occurred much earlier in the day. Twenty-six of these flights were from outside the continental limits of the United States. Fourteen of these 26 flights returned to JFK or LGA after AFCP were cancelled. The delay for these aircraft prior to electing to divert ranged from about one hour and forty-five minutes (1 + 45) maximum to zero (0) minutes. There were 14 additional returnees whose points of departure were within the continental limits of the United States.

The diversions and returns are plotted vs. time in Figure 12. It can be seen from this figure that diversions in large numbers began at JFK in the 1900Z hour and continued through the 2200Z hour and then sporadically through 2700Z. Nine out of the 59 JFK diversions and 3 out of the LGA diversions occurred outside the AFCP hours.

Cancellations

The number of regularly scheduled flights that were cancelled on February 5 could not be determined directly from available records, since they are not normally retained. An approximation was obtained, nevertheless, by extracting from the OAG all flights not appearing in the flight strip data. Since the OAG issue was less than 5 days old on February 5, it may be taken as a reasonably good approximation to the air carrier schedules, and OAG flights that do not appear on the flight strip data are assumed to be cancelled in the sense that they did not reach ZNY on the scheduled day under their scheduled ID.

The number of non-scheduled flights that were cancelled on February 5 could not be determined from available records, either. Undoubtedly, many intended flights were cancelled without any reservation or record of intent being made. One way to estimate the number of cancellations among non-scheduled flights is to assume that the same proportion of cancellations holds for the non-scheduled as for the regularly scheduled flights. The numbers so obtained are followed by question marks in the following tabulation:

"CANCELLED"		ARRIVED IN ZNY		
Scheduled	Non-Scheduled	Scheduled	Non-Scheduled	
123	40?	280	90	(JFK)
95	18?	278	52	(LGA)

If attention is restricted to the data on scheduled flights, one may reasonably ask whether or not AFCP had any perceptible effect on cancellations. Figure 13 and Table 7 show cancellations among flights as percents of the hourly schedule with and without cancellations.

It can be calculated from this table as well as from the figures, that cancellations, as reflected in arrivals, were about 48% of the schedule prior to the announcement of the AFCP, and about 33% for the three hours after the announcement. They then averaged about 19% from 11 a.m. to 8 p.m. The increase in cancellations after 8 p.m. shown in Figure 13 is only apparent, and is due to lack of arrival data after 12 p.m.

TABLE 7

CANCELLATIONS AS PERCENT OF SCHEDULE BY ARRIVAL HOUR FOR 5 FEBRUARY

EST HOUR	GMT HOUR	SCHEDULED ARRIVALS IN THE HOUR INCLUDING CANCELLATIONS		SCHEDULED ARRIVALS IN THE HOUR EXCLUDING CANCELLATIONS		PERCENT CANCELLATIONS		NUMBER OF CANCELLATIONS	
		JFK	LGA	JFK	LGA	JFK	LGA	JFK	LGA
1200A	0500	17	6	14	5	18	17	3	1
100	0600	11	2	6	0	45	100	5	2
200	0700	10	0	8	0	20		2	0
300	0800	10	1	9	0	10	100	1	1
400	0900	3	2	2	0	33	100	1	2
500	1000	3	0	2	0	33		1	0
600	1100	13	0	6	0	54		7	0
700	1200	10	8	5	6	50	25	5	2
800	1300	16	25	9	16	44	36	7	9
900	1400	13	23	13	17	0	26	0	6
1000	1500	16	27	7	17	56	37	9	10
1100	1600	13	30	11	28	15	7	2	2
1200P	1700	28	24	21	19	25	21	7	5
100	1800	25	27	22	21	12	22	3	6
200	1900	24	22	21	19	13	14	3	3
300	2000	41	30	28	24	32	20	13	6
400	2100	38	29	32	25	16	14	6	4
500	2200	39	32	28	26	28	19	11	6
600	2300	35	27	30	21	14	22	5	6
700	2400	27	27	23	21	15	22	4	6
800	0100	33	28	25	23	24	18	8	5
900	0200	30	24	21	22	30	8	9	2
1000	0300	26	19	17	12	35	37	9	7
1100	0400	6	7	3	2	50	70	3	5

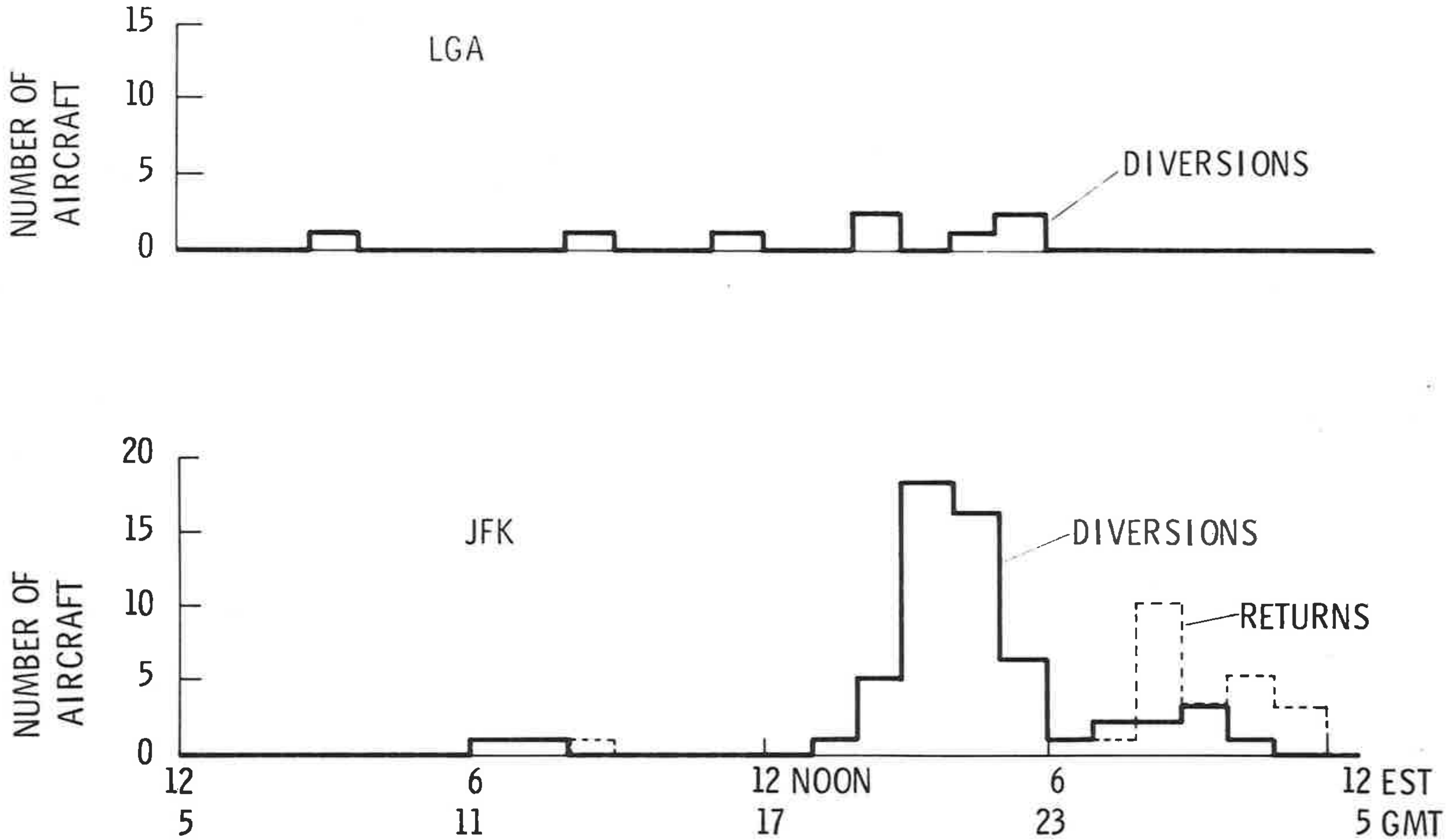

Figure 12. Diversions and Returns for 5 February 1971

CANCELLATIONS AS A PERCENT OF THE ORIGINAL SCHEDULE

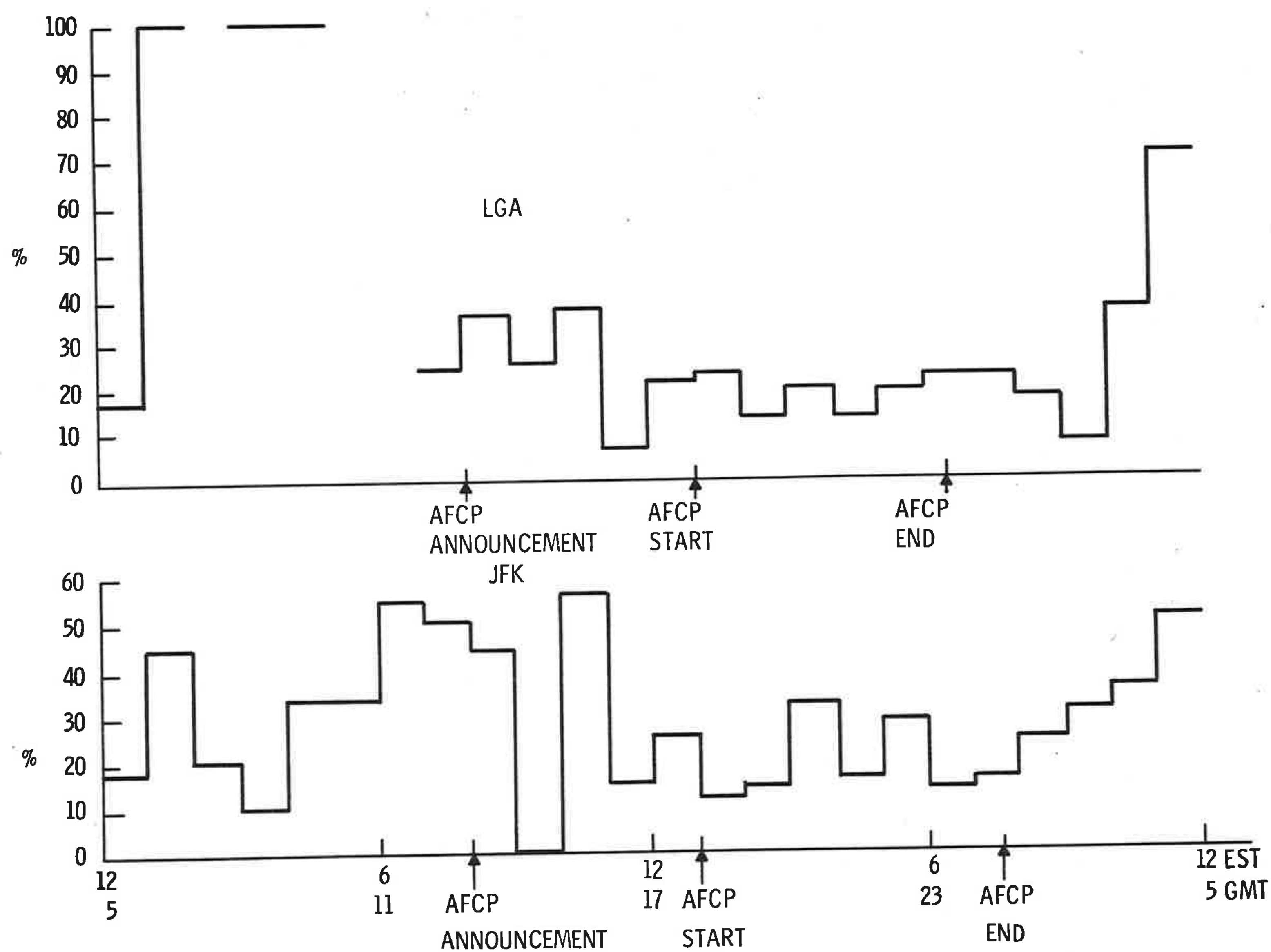

Figure 13. Cancellations

These cancellation data, then, indicate a slight drop in percent cancellation during the hours that AFCP were in effect, which seems to suggest that AFCP had some effect in reducing cancellations. This can be accepted only with qualification, however, because (a) the data are rather scarce for the morning hours in which the higher percentages occurred, (b) the effect is not pronounced, (c) the true cancellations may be considerably different because the data are incomplete, and (d) many cancellations undoubtedly were due to weather, runway plowing in the morning, equipment problems and conditions other than New York traffic (example: Job action by Mohawk employees).

Air Delays Outside New York Center

The data indicate a large number of enroute delays that are small (less than 10 minutes) or negative. These are within the range of normal enroute delays. They also are within the range of expected data inaccuracy, since exact departure times often were not available on the strips and they had to be estimated. Also, the available arrival times are only approximate, having been obtained by the approximations described in Appendix C. Hence negative and small enroute delays were not considered to indicate backups into adjacent centers.

The data also contain many air files, for which no accurate departure times are available. These also were ignored in determining backups. Finally, enroute delays for which the ground delay is a substantial negative number (i.e., less than -15 minutes) have been ignored since such negative ground delays more likely indicate an error in the departure time shown on the flight strip data than an actual early departure.

What remains may be considered a measure of enroute delay and indirectly of backups into centers outside of New York Center. The numbers obtained are 20 aircraft hours for JFK and 19 for LGA. It should be emphasized that these are only indirect measures of backups into adjacent centers, because they include ATC delays outside ZNY due to causes other than backed-up traffic destined for ZNY.

EFFECTIVENESS OF AFCP ON FEBRUARY 5, 1971 - ACTUAL CONDITIONS

In calculating effectiveness measures from the available data, several assumptions and approximations were made. These are given in detail in Appendix C. The two major ones are as follows.

First, it was necessary to approximate the minimum time required to go from each entry fix to landing, assuming no air delays. The times obtained directly from the flight strips included air delays. Therefore, only the shortest 10% of those times were selected, for those fixes that had more than 20 data points, and used as the basis for calculating fix-to-landing time as a linear function of distance-to-landing. Once the minimum time from fix-to-landing was obtained it was easy to add it to the fix posting time to get available arrival time, TA*, and then delays, etc.

Secondly, it was necessary to estimate the actual arrival capacities. With the aid of the available arrival times, and the actual arrival times, it was possible to determine the number of aircraft delayed at any time. When this reached 4 or more it was assumed that the airport was in saturation for that hour and the arrival capacity was taken to be the actual arrivals in that hour. For hours in which the number waiting did not reach 4, the capacity was interpolated or extrapolated linearly, but not less than actual arrivals. Both airports were in saturation for most of the time after 1400Z.

With the above approximations, the data were examined to obtain the effectiveness measures developed in the section entitled MEASURES OF EFFECTIVENESS of this report. The principal results are summarized in Figures 14 through 20 and Table 8.

Several things are immediately apparent from these figures. Consider Figure 14, the cumulative plot of JFK arrivals. First, it can be seen that there were substantial percentages of cancellations from the very beginning of the day, as indicated by the difference between the scheduled arrivals and the available arrivals without diversions. This is also true of LGA, as seen in Figure 15. Without knowledge of these cancellations, no AFCP scheme could be expected to work effectively, for demand would be grossly over-estimated. Since the KC computer was not functioning when the AFCP were decided upon, the extent of cancellations could be known to NYARTCC only approximately through the ARO. (In fact, they relied heavily on traffic records of previous Fridays to estimate demand, but the extent of cancellation data on those days could not be determined either.) Even if the computer were functioning, however, the ARO could not have provided the cancellation information required to make up accurate allocation lists (ID, origin, destination) because this information is not normally provided to ARO by the air carriers.

TABLE 8

EFFECTIVENESS MEASURES FOR AFCP ON 5 FEBRUARY, 1971

	JFK	LGA
COMBINED DELAY MEASURE	656 AIRCRAFT HOURS	235 AIRCRAFT HOURS
AIR DELAY IN ZNY	225	72
DELAY DUE TO DIVERSIONS (1)	276	88
DELAY DUE TO DIVERSIONS (2)	123	-
ENROUTE DELAY	20	19
LOST CAPACITY	12	56
DISTRIBUTIONS OF AIR DELAYS IN ZNY		
NUMBER OF A/C VS. DELAY	FIGURE 12	FIGURE 13
MEAN VALUE	1.61 HRS	0.44 HRS
STANDARD DEVIATION	2.48	1.66
MAXIMUM	16.83	15.20
AVERAGE DELAY VS. ETE	FIGURE 15	FIGURE 15
DISTRIBUTIONS OF GROUND DELAYS		
NUMBER OF A/C VS. DELAY	FIGURE 12	FIGURE 13
MEAN VALUE	0.44 HRS	0.46 HRS
STANDARD DEVIATION	1.17	0.65
MAXIMUM	10.0	5.0
AVERAGE DELAY VS. ETE	FIGURE 15	FIGURE 15
(1) NON-RETURNEES		
(2) RETURNEES		

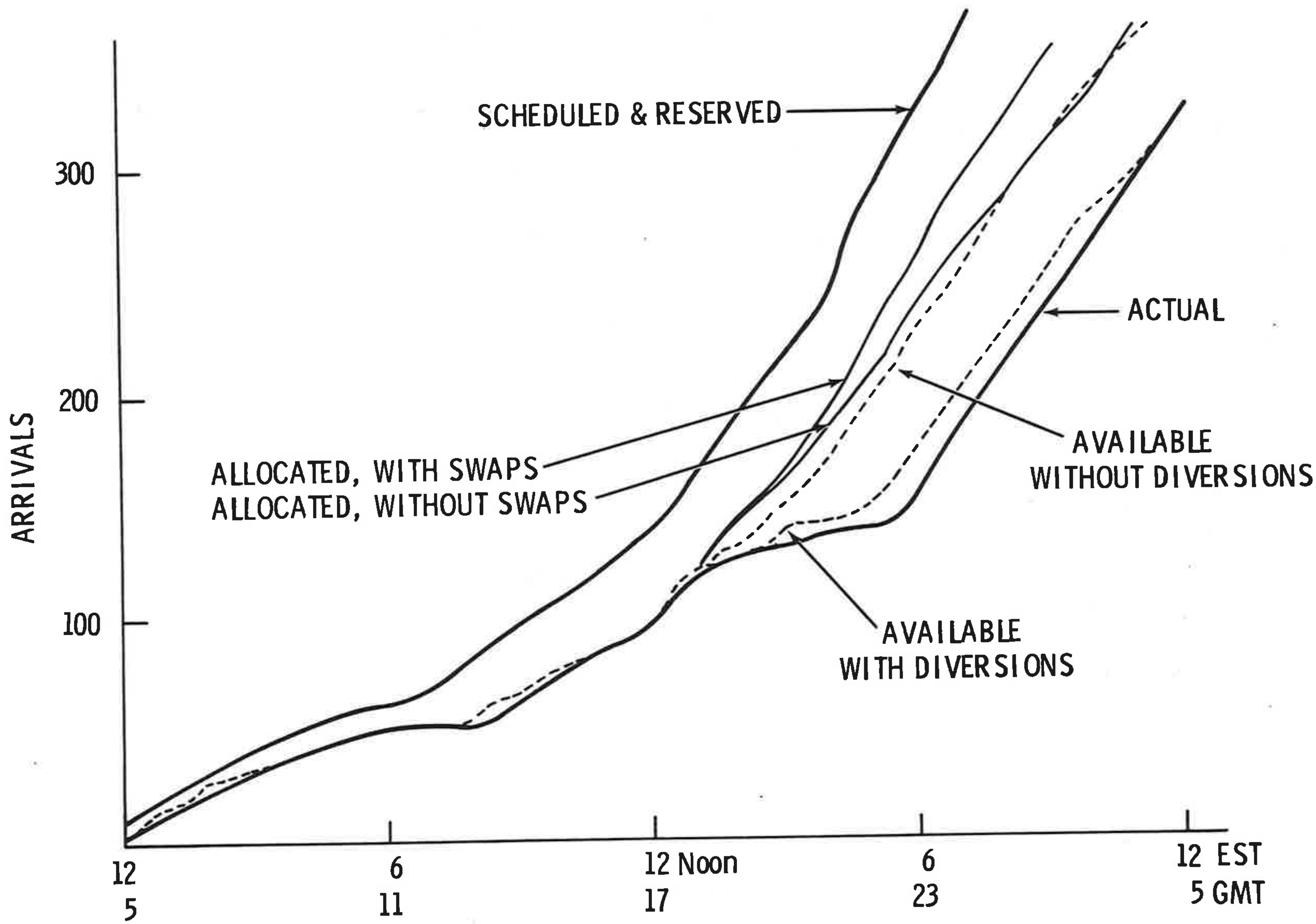

Figure 14. 5 Feb. 71: Cumulative Arrivals at JFK

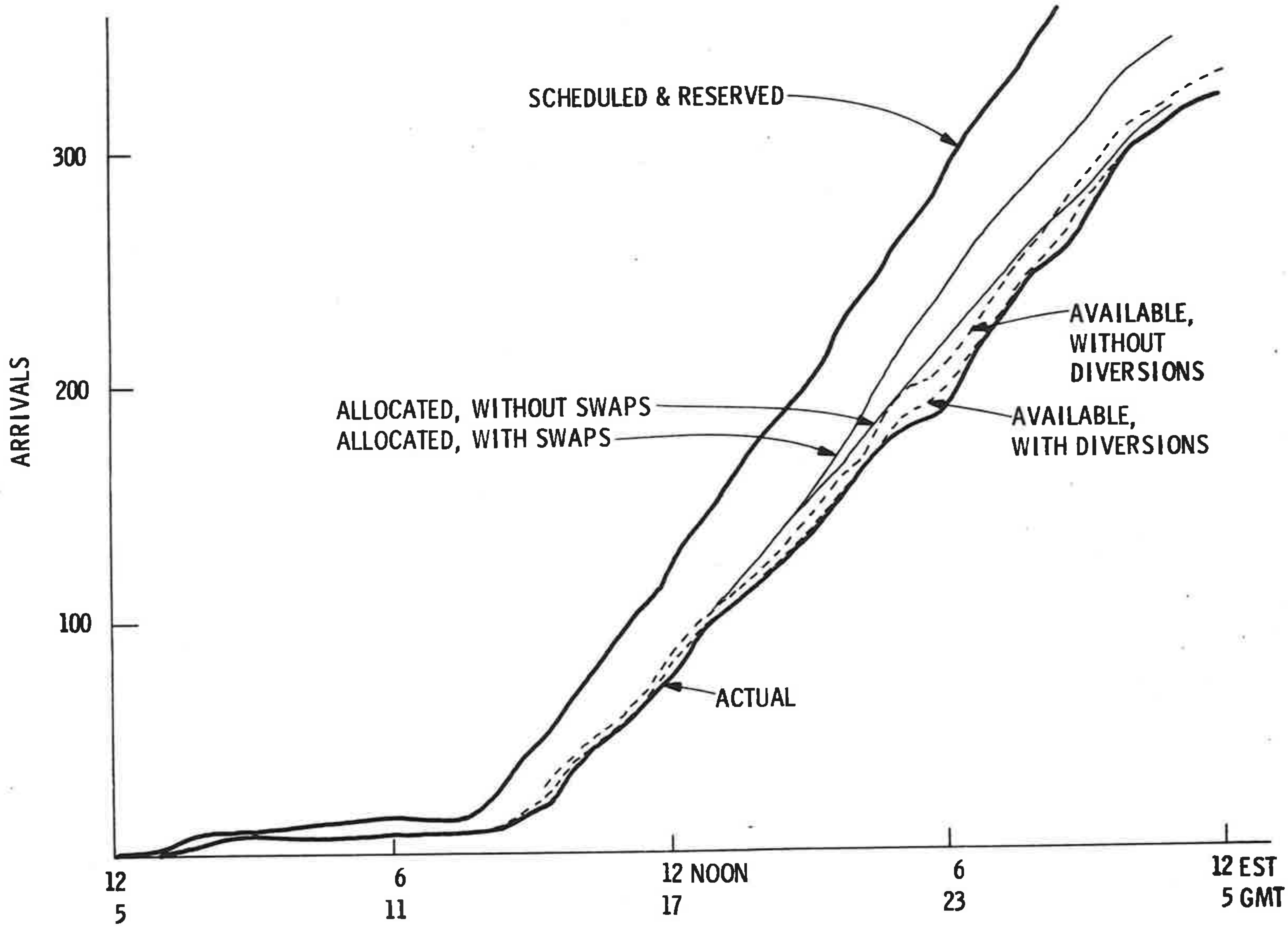

Figure 15. 5 Feb. 71: Cumulative Arrivals at LGA

Figure 16

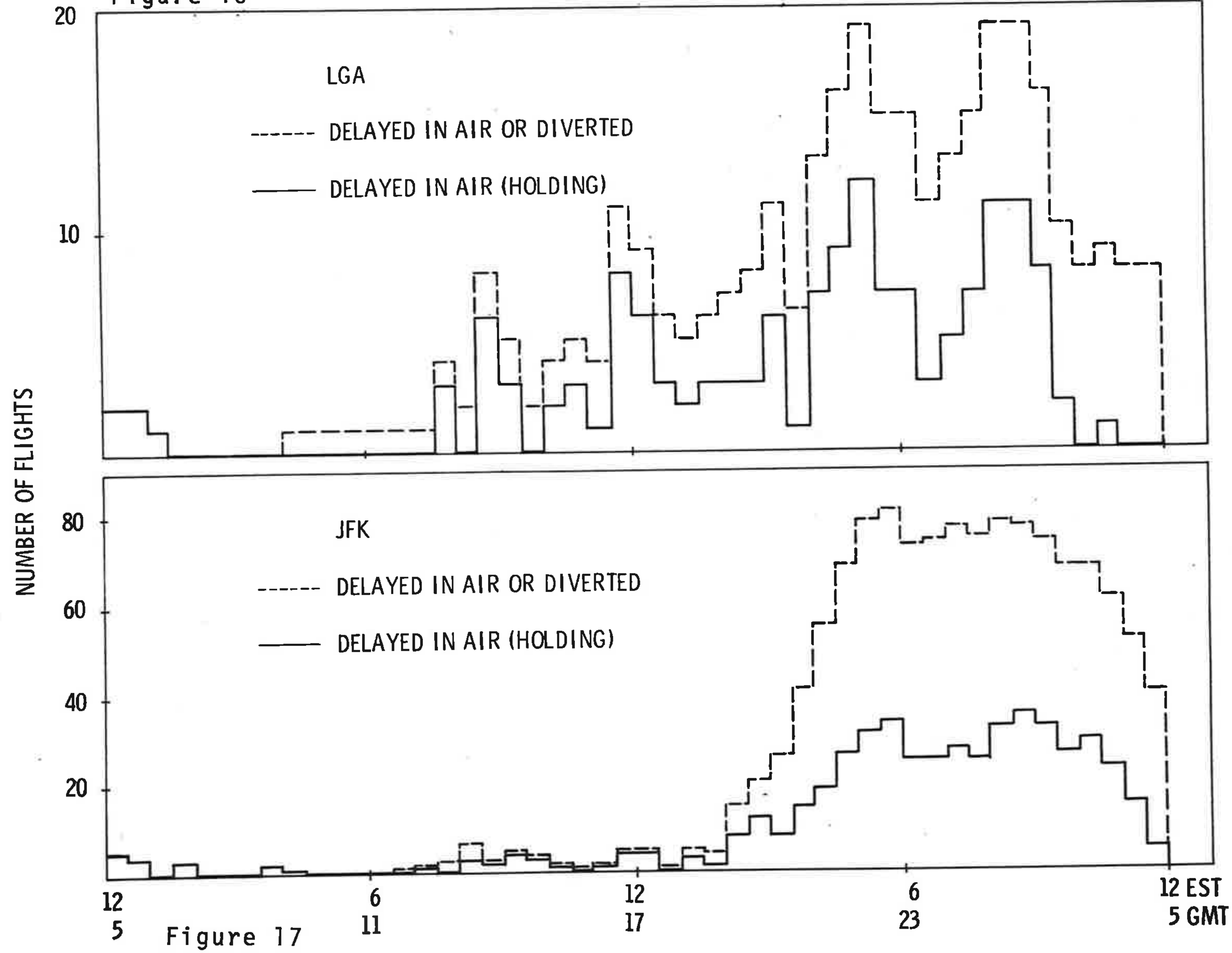

Figure 16/17. Hourly Air Holds and Diversions, 5 Feb. 1971

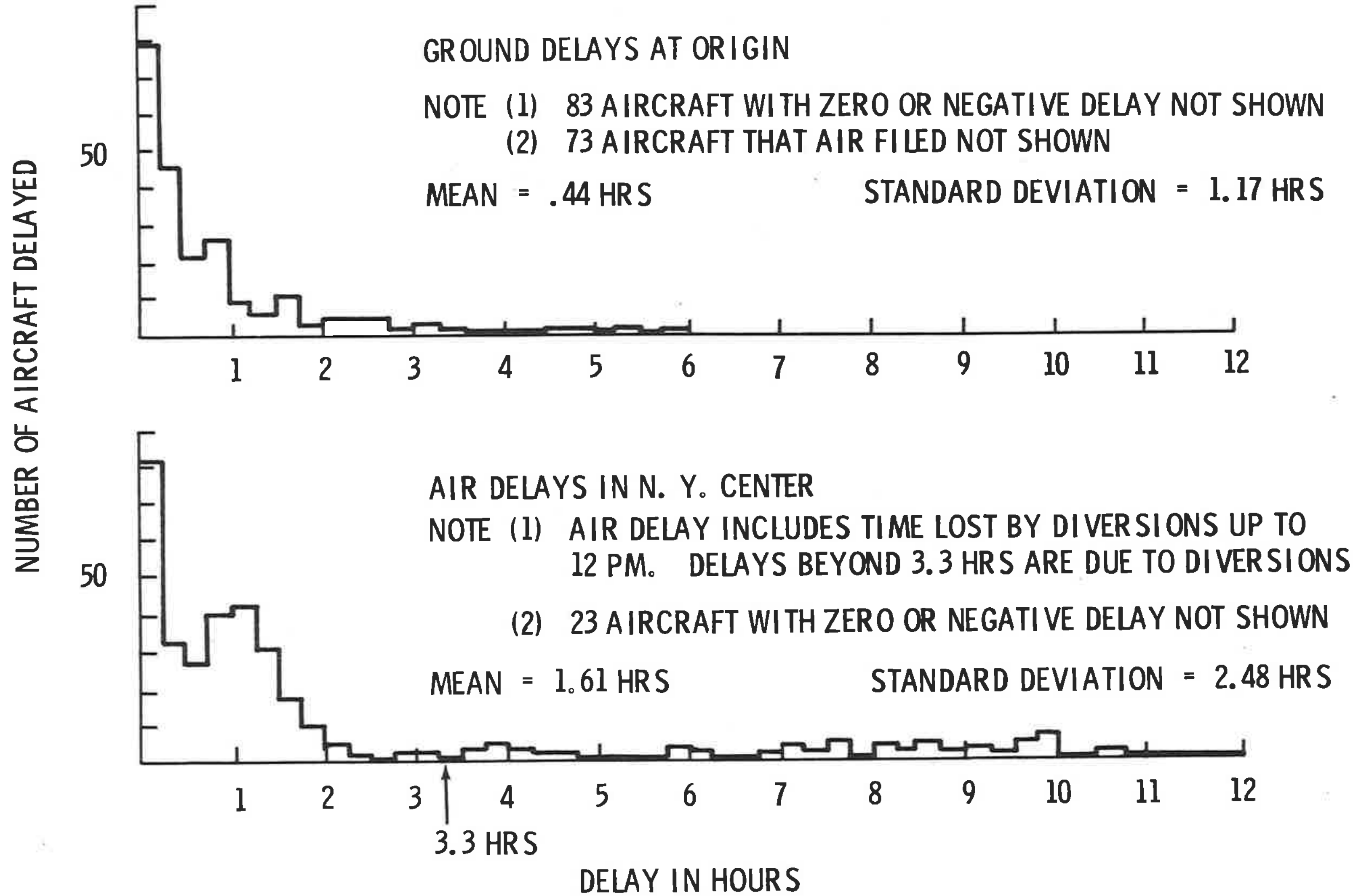

Figure 18. Distribution of Delays for JFK on Feb. 5, 1971

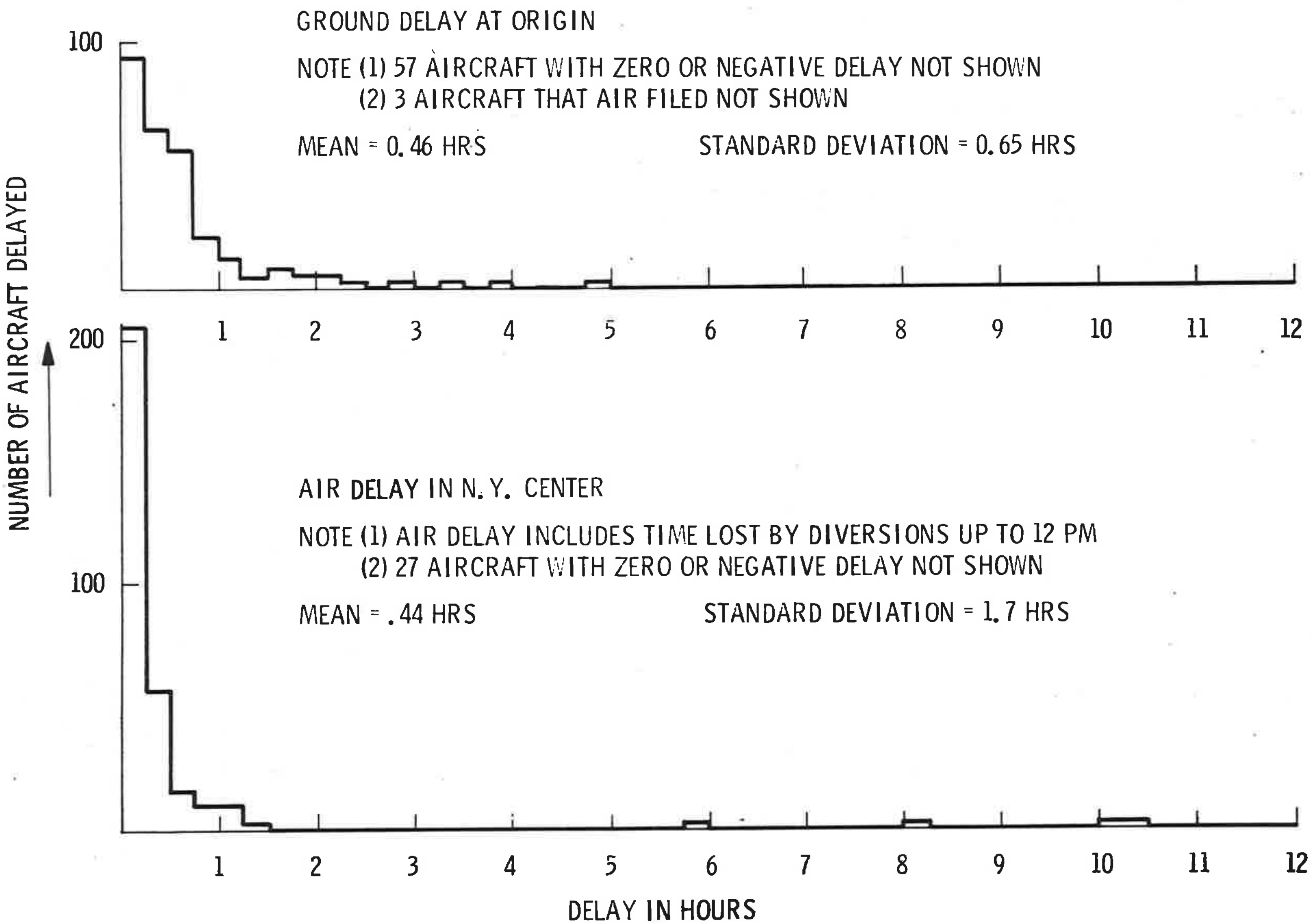

Figure 19. Distribution of Delays for LGA on Feb. 5, 1971

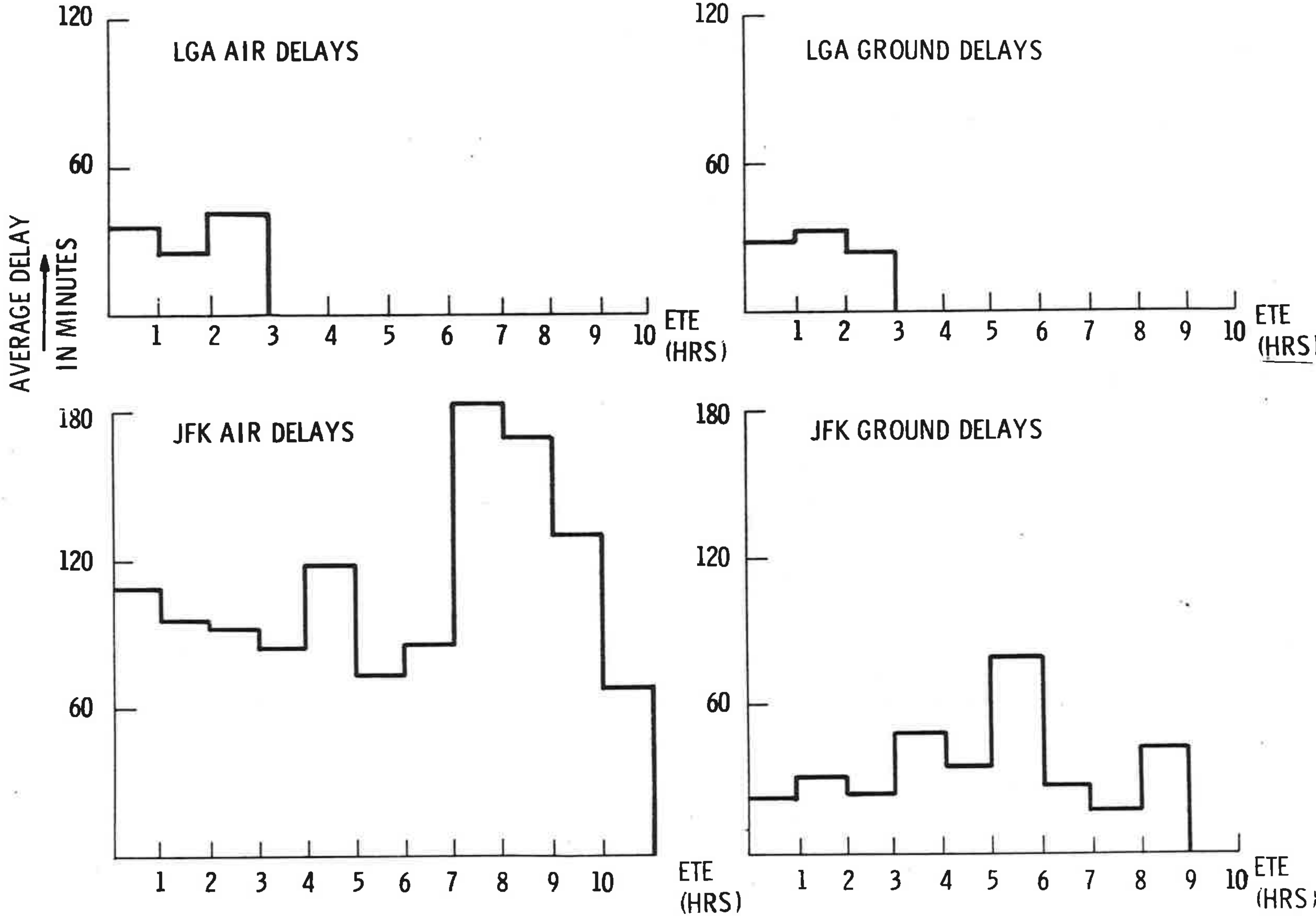

Figure 20. Average Delay vs. ETE

It can be seen from Figures 15 and 16, secondly, that the cumulative initial allocations issued by NYARTCC agree with the available arrivals at JFK and LGA, within about a dozen flights, starting from 1800Z. But when the revised allocations are plotted (Figures 14 and 15) it is seen that they exceeded available arrivals by some 30-40 aircraft by the end of the AFCP period. The conclusion, then, is that the swappings, and probably the original allocations, were made not only without reference to the estimated capacities, but also without accurate cancellation data.

Thirdly, it is seen from Figure 14 that without the substantial numbers of diversions that took place, the delays for JFK would have been two or three times as large. Note that on a cumulative plot the horizontal difference between available arrivals and actual arrivals equals air delay, and the vertical difference equals stack size. The stacks that would have occurred are plotted as dashed lines in Figures 16 and 17 (note the difference in scale between JFK and LGA). A peak of 80 aircraft would have occurred at JFK at 6 p.m. The diversions can be only partly attributed to the ILS failures on Runway 22 at JFK. The two failures of the ILS totalled 34 minutes and occurred between 1859Z and 1949Z, while 53 of the 58 JFK diversions occurred outside the 1900Z hour. Rather, the diversions seem to be directly related to the number holding, as seen in Figure 16.

The distribution of air and ground delays at JFK is shown in Figure 18. The air delays extend out to two hours, with numerous delays scattered out as far as 11 hours. The delays lying out beyond 200 minutes are all due to diverted flights, both returning and and non-returning. Even without the diverted flights, however, it is apparent that air delays were not held to one hour at JFK. Moreover, the ground delays, to which air delays should have been converted, do not extend appreciably beyond two hours and, in fact, 83 percent of them are concentrated under one hour. An effective AFCP operation would have reversed the distributions of ground and air delays shown in Figure 18.

The distribution of delays for LGA is shown in Figure 19. The AFCP were apparently more successful here than at JFK. Air delays were held to substantially less than one hour, while ground delays extended out to 45 minutes and more.

Finally, Figure 20 shows that the delays were approximately equitably distributed over the country. The large values of average air delays for JFK flights with ETE's between 7 and 10 hours are due primarily to foreign origination flights; these foreign flights were almost all air files and most arrived in the afternoon when delays were the greatest. Six of the 42 flights with ETE's between 7 and 10 hours were diverted and did not return that day under the same flight number; six more of the 42 were diverted and returned. With the exception of the foreign flights, however, ETE seems not to be a factor in the distribution of average delays, either air or ground.

Table 8 shows the effectiveness measures for the actual occurrences of February 5. The aircraft hours lost at JFK were almost three times those at LGA. The JFK losses were greatest in diverted flights, particularly those that did not return, and least in lost capacity. The LGA lost capacity was several times that at JFK because LGA did not experience the same sudden and unexpected capacity drop.

EFFECTIVENESS OF AFCP ON FEBRUARY 5, 1971 - MODIFIED CONDITIONS

The preceding discussion dealt with AFCP effectiveness measures for the actual occurrences of February 5, as summarized in Table 8. Due to the failure of the ZKC computer and the extensive cancellations on that day, the results are not fully representative of AFCP's effectiveness when the necessary information is available. Important questions such as sensitivity to errors in landing capacity estimates, allocation rules, weather and times enroute remain to be investigated, and the next section will present the answers obtained under more realistic conditions using the VAST simulation. Nevertheless, some useful information can be extracted from the data by calculating effectiveness measures when only certain conditions are modified.

Modified Conditions

The conditions that were selected to be varied are the major parameters presently under AFCP control: New York acceptance rate estimates, minimum anticipated air delay at New York for initiation of AFCP, the assigned air hold time at New York during AFCP periods, and the maximum notification time (time from notification to arrival). In varying these parameters, however, it was necessary to make some assumptions, in addition to those previously mentioned. These additional assumptions are given in Appendix C. The most important are as follows:

1. It was assumed that individual flights with anticipated delays greater than the threshold level were dispatched (without weather delay), so as to have the desired delay at New York, based on ETE.
2. It was assumed that new allocations were calculated and issued each hour.
3. Diverted flights were counted as air holds until the flight could land or until 0500Z on February 6, whichever occurred first.

4. Complete cancellation information was assumed to be available, i.e., flights not in the NAFEC data were assumed to be cancelled.
5. Flights not dispatched under AFCP had the same departure times as on February 5, whether due to ground hold or to weather.

The results of the calculations are summarized in Table 9 and Figures 21 and 22. Case 0 of the table is the actual occurrences, as discussed previously and summarized in Table 8. It forms a reference case against which the other cases may be measured. The enroute air delays have been excluded from Table 9, because they are the same for all cases: 20 hours for JFK and 19 hours for LGA.

Landing Capacity Estimates, Assigned Air Holds and Initiation Criterion (Cases 1-6)

Results for LGA

Case 1 of Table 9 shows what the measures would have been if AFCP had been applied under the stated assumptions using the ZNY estimate of 20 per hour to release departures. There would have resulted a reduction in air delay to 50 aircraft hours due mainly to landing of diverted flights, but this would be almost offset by an increase in lost capacity. This result is just what would be expected, since 20 per hour is a low estimate of the actual LGA capacity, which averaged about 24, as approximated in Table 16, Appendix C. When the estimated capacity for LGA was set at 25, as in Case 2, it was found that no aircraft were held on the ground, and that the effectiveness measure dropped to 133 from 216. This improvement relative to case 0 also is due entirely to landing of diverted flights; there is no counteracting lost capacity because no flights are held.

In general, Figure 21 shows the effectiveness of AFCP as a function of the estimated landing capacity, when the latter is assumed to be constant throughout the AFCP period. Any estimate above about 24/hour (the actual average capacity) would have resulted in an improved effectiveness (133 aircraft hours) compared to actual events (216 aircraft hours) because, under the assumptions of the calculation, all flights waited in the air to land rather than be diverted. But the figure shows that as the estimate drops below 24/hour, the losses increase rapidly. Obviously, the demand and actual capacity at LGA were close enough on February 5th that about the only way for flow control to improve the effectiveness of the operation would have been to encourage the diverted flights to await their turn to land, e.g., by providing accurate landing delay predictions.

TABLE 9 EFFECTIVENESS MEASURES FOR FEBRUARY 5 - UNDER MODIFIED CONDITIONS

CASE NO.	0	1	2	3	4	5	6	7	8	9	10	UNITS
CONDITIONS												
CAPACITY LGA	20	20	25	A	A	A	A	A+5	A+4	A+4	A+6	ARRIVALS
ESTIMATE JFK	28	28	25	A	A	A	A	A+5	A+4	A+4	A+6	PER HR
ANTICIPATED AIR DELAY FOR INITIATION	60	60	60	60	60	60	30	60	60	30	60	MINUTES
ASSIGNED HOLD AT ZNY	?	0	0	0	30	60	0	0	0	0	0	MINUTES
NOTIFICATION TIME	8	12	12	12	12	12	12	5	4	4	6	HOURS
LGA EFFECTIVENESS MEASURES												
TOTAL AIR DELAY	160	50	78	78	78	78	78	78	78	71	78	AIRCRAFT HRS
LOST CAPACITY	56	147	55	55	55	55	52	55	55	59	55	AIRCRAFT HRS
TOTAL	216	197	133	133	133	133	130	133	133	130	133	AIRCRAFT HRS
JFK EFFECTIVENESS MEASURES												
TOTAL AIR DELAY	624	603	598	72	157	254	72	159	214	218	129	AIRCRAFT HRS
LOST CAPACITY	12	12	12	14	12	11	13	123	56	59	162	AIRCRAFT HRS
TOTAL	636	615	610	86	169	265	85	282	270	277	291	AIRCRAFT HRS

TABLE 9 (CONT.)

LGA - OTHER INDICATORS												
NUMBER HELD UNDER AFCP (1)	?	115	0	0	0	0	62	0	0	26	0	FLIGHTS
MAX AFCP GROUND DELAY (1)	?	106	-	-	-	-	50	-	-	56	-	MINUTES
MAX AIR DELAY	912 (2)	59	60	60	60	60	58	60	60	60	60	MINUTES
JFK OTHER INDICATORS												
NUMBER HELD UNDER AFCP (1)	?	0	10	240	239	240	242	167	145	143	187	FLIGHTS
MAX AFCP GROUND DELAY (1)	?	-	66	201	171	141	201	383	349	349	416	MINUTES
MAX AIR DELAY	1011 (3)	187	187	88	88	94	88	152	164	164	138	MINUTES

NOTES (1) FOR ARRIVALS AFTER 1800Z.
(2) 72 IF DIVERTED FLIGHTS ARE NOT COUNTED.
(3) 197 IF DIVERTED FLIGHTS ARE NOT COUNTED.

A INDICATES ACTUAL CAPACITY, GIVEN IN TABLE 7.
A+y INDICATES ACTUAL CAPACITY, GIVEN IN TABLE 7, APPLIED TO ARRIVALS y HRS LATER.

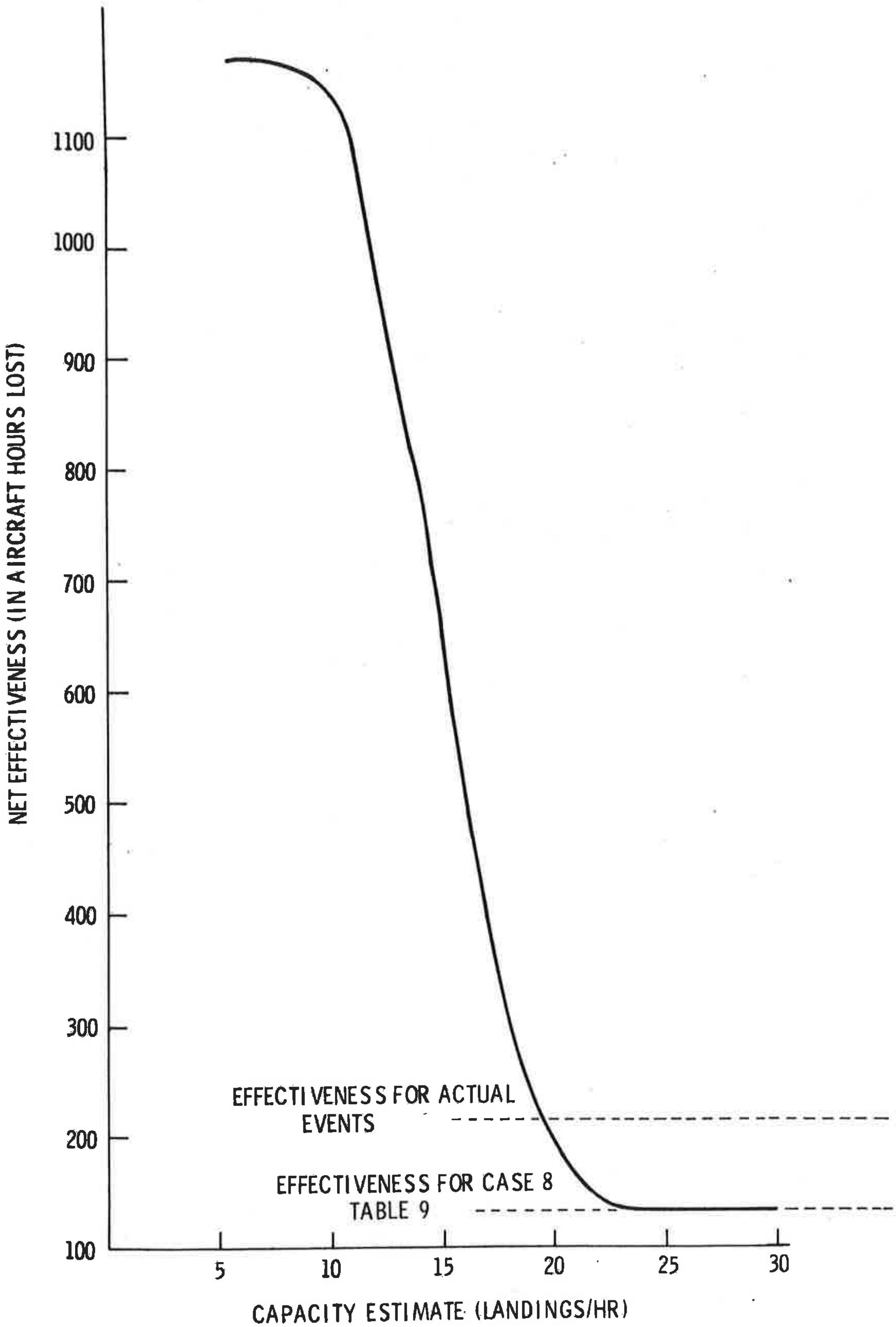

Figure 21. Effectiveness as Function of Capacity Estimate-LGA

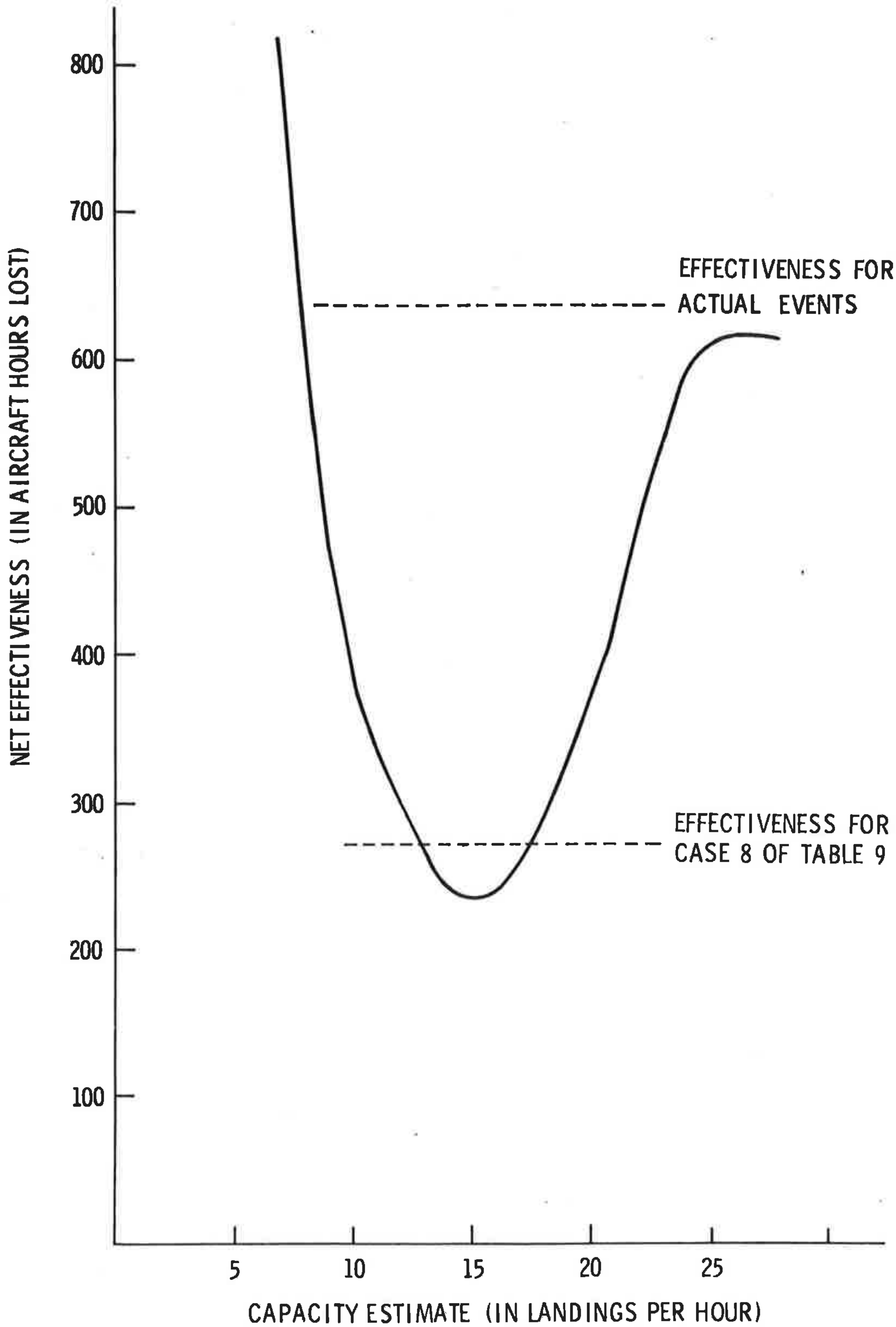

Figure 22. Effectiveness as Function of Capacity Estimate-JFK

Cases 3, 4, and 5 were intended to show the effect of different assigned air holds at New York but they only show that if perfect predictions of landing capacity were available, anticipated air delays would not have exceeded one hour and AFCP would not have been instituted. Case 6 shows that if the criterion for instituting AFCP were set at 30 minutes anticipated air delay, then about 62 flights would have been detained, but the overall performance would have been hardly better than actually occurred.

Results for JFK

Turning now to JFK, one obtains a very different picture from Figure 22. If capacity had been estimated at 25 to 30/hour, the losses would have been only slightly less than actual events. (Again the difference is due to the treatment of diverted flights in the calculation.) But if the capacity estimate had been made between 10 and 20/hour, and AFCP carried out according to the assumptions, the net losses would have fallen in the valley of Figure 22, between the extremes of excessive lost capacity on the left and excessive air delay on the right. The best achievable measure for JFK is not as good as that for LGA because a single number could not be used to approximate JFK capacity as well as LGA capacity (see Figure 14).

Given that a capacity estimate of 10-20/hour would have produced much lower losses for JFK, the question arises: How could the New York flow controllers have made the better estimate? It will be shown in the next section that simply updating the landing capacity estimate each hour, according to observed capacity, would have produced an effectiveness measure for both airports close to the best achievable by a single, fixed estimate.

Some further results are shown in Table 9:

1. If capacity were estimated perfectly, a sharp improvement over actual events would have occurred as expected (Cases 3 through 6).
2. Effectiveness improves steadily as the assigned air hold at ZNY decreases to zero (Cases 3, 4, 5).
3. A 30 minute initiation criterion produced no better results than a 60 minute criterion (Case 6 compared to Case 3).

Notification Time and Landing Capacity Estimates (Cases 7-10)

Perfect landing capacity predictions are impossible in practice but reducing the prediction time should improve their accuracy. As the prediction time for landing capacity is reduced, however, shorter notification times are necessary. The notification time, or time from issuance of allocation or ATA to the applicable arrival time, should be long enough to encompass enough un-departed flights to produce effective control. The columns of Table 10 show how the flights planning to arrive in any PTA hour are distributed among the PTD hours, for JFK and LGA. It can be seen that to control all flights at JFK in, say, the 1700 arrival hour, a notification time of at least 10 hours is required; but a notification time of 4 hours will still encompass at least half of the arrivals in that hour. Since shorter prediction times will probably improve capacity prediction accuracy, and hence performance, it is useful to determine how short a notification time is still effective.

Cases 7, 8, and 10 of Table 9 assume notification times of 5, 4, and 6 hours, respectively. Landing capacity was predicted simply by taking the actual landing capacity observed at time of notification and applying it to the arrival hour (i.e., 5, 4, or 6 hours ahead). The results for JFK show from 270 to 291 aircraft hours lost compared to over 600 aircraft hours lost in actual occurrence or for AFCP with an estimate of 25 or 28 per hour (Cases 0 through 2). For LGA, the results are not as pronounced, but still favorable. It should be noted that the 4 hour notification excluded flights with ETE's in excess of 3 hours by assumption 0 above. Also, allocations were assumed to be issued continuously from 4 hours before the first AFCP arrival hour, to 4 hours before the last AFCP arrival hour.

The allocation rules used in Cases 7, 8 and 10 are less sophisticated than the current KC computer program in that the current program allows repeated re-estimation of landing capacity for future hours and repeated re-issuance of the allocations (not closer than 30 minutes, however). But the notification times in the present KC Program are set at 4, 6 and 8 hours for zones I and IV, II, and III respectively. Also, the allocations are presently issued in 4-hour blocks, rather than the one-hour block assumed in the cases calculated.

The most favorable of these modified cases, case 8, was analyzed in some detail so as to compare it with the actual events. The results are given in Figures 23, 24 and 25. These correspond to Figures 18, 19 and 20 for the actual events. It can be seen from Figures 23 and 18 that the large number of the actual air delays at JFK between 0 and 2 hours and beyond 3 hours would have been exchanged for a very large number (over 200) of delays less than 15 minutes plus about 70 delays in the 100- to 160-minute range. The situation at LGA would not have been very different from actual events.

TABLE 10. NUMBER OF AIRCRAFT FOR GIVEN PTA AND PTD - JFK

PTD HOUR \ PTA HOUR	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
0100			1		1						1	2																
0200																												
0300			2		6		1																					
0400					4	3	1				1		1															
0500					2	1	2	1	1																			
0600						2	3	3		1	1																	
0700							1	3					1															
0800								2	1	1			1				1											
0900																	1	1										
1000											1						3	1	1									
1100												2	1	2	1			4	3	2								
1200												3	4	2	1				2	4	3							
1300													1	6	2	2		2		1	4							
1400														3	2	5	6	1	1		1	2						
1500																2	7	1	1	2								
1600																	3	4	1	4	5		2	2	1			
1700																	1	8	4	2	1	5	1	2				
1800																			7	10	4	4	4		1			
1900																			2	4	5	4	6	3				
2000																					7	5	4	2	1			
2100																						9	8	4	1	5		
2200																							4	6	7	4	1	1
2300																								4	5	6	5	
2400																								1	6	1		
2500																									2	6	2	
2600																											8	
2700																											2	2

TABLE 11. NUMBER OF AIRCRAFT FOR GIVEN PTA AND PTD - LGA

PTD HOUR \ PTA HOUR	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900
0100																													
0200			1	1																									
0300				2	3																								
0400				1	2																								
0500																													
0600																													
0700																													
0800																													
0900																													
1000																													
1100												1	1																
1200												4	9	3	1														
1300													3	13	7	1													
1400														2	6	7	2												
1500															2	19	2												
1600																3	14	4											
1700																	1	13	5										
1800																		3	9	7	2								
1900																			7	9	3								
2000																				7	15	3	2						
2100																					6	17	3	1					
2200																						4	16	6	2				
2300																								12	8	1			
2400																								1	11	10			
2500																									4	9	1		
2600																										2	7	1	
2700																											5	2	

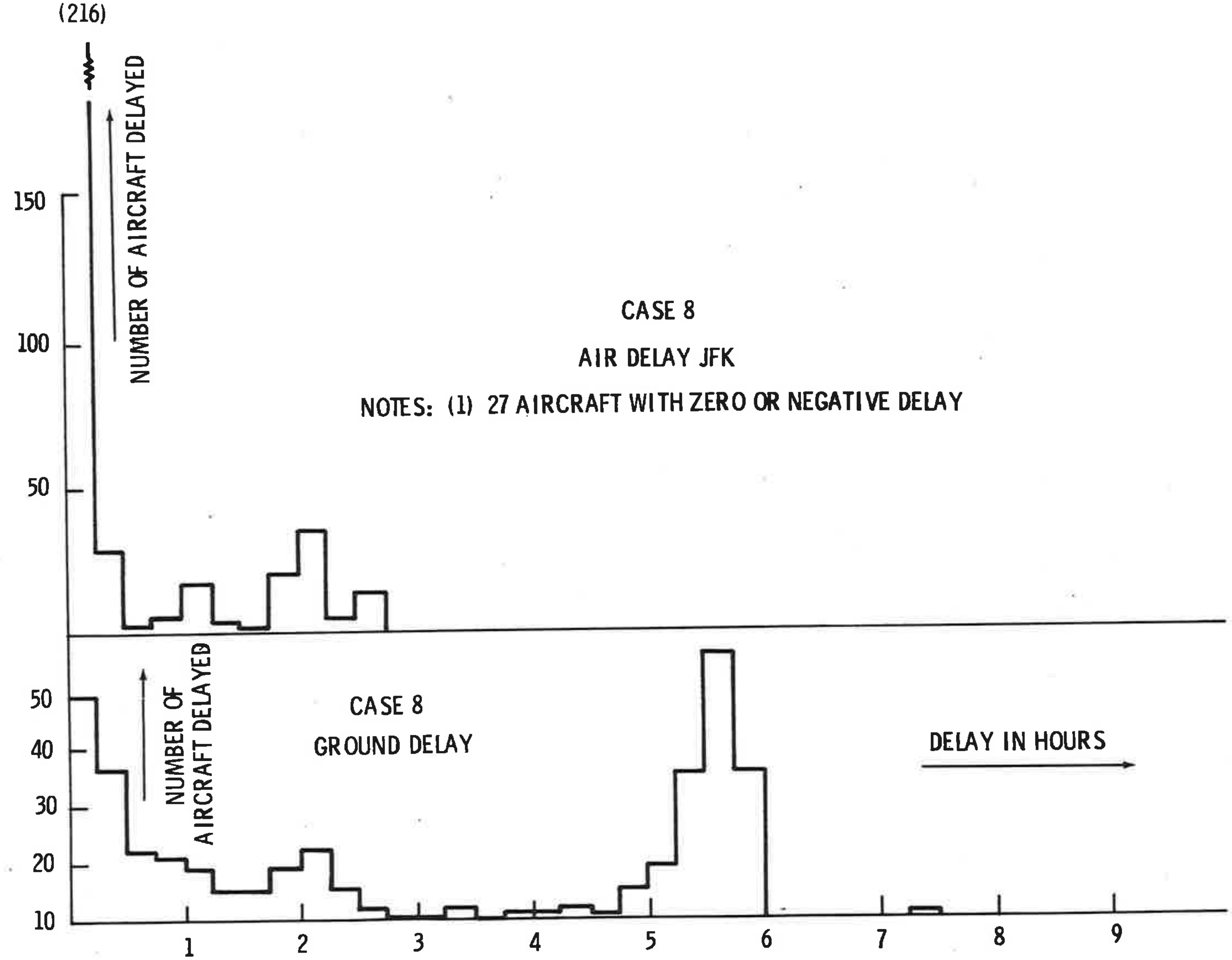

Figure 23. Distribution of Delays for JFK, Conditions of Case 8 of Table 9

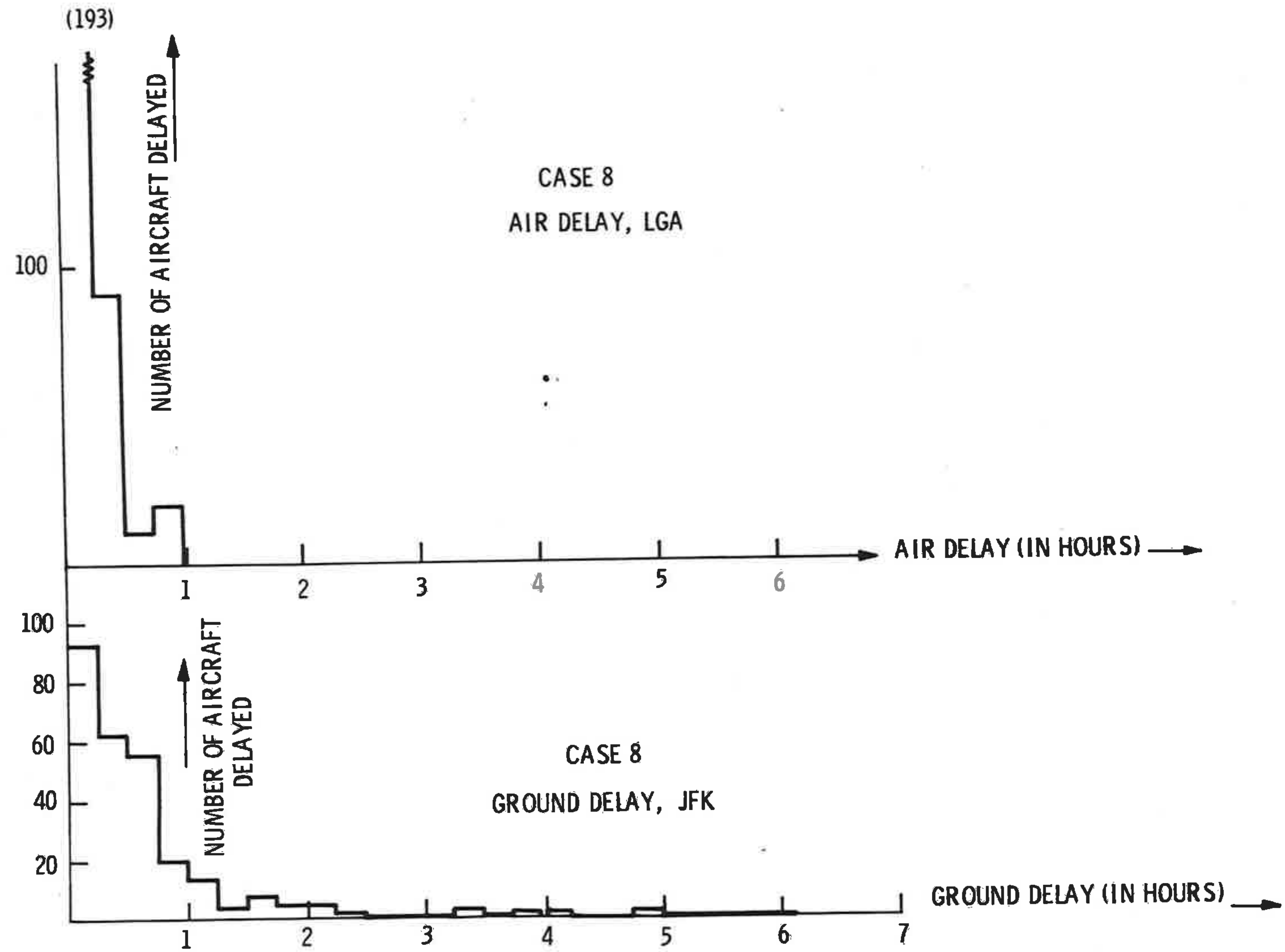

Figure 24. Distribution of Delays for LGA, Conditions of Case 8 of Table 9

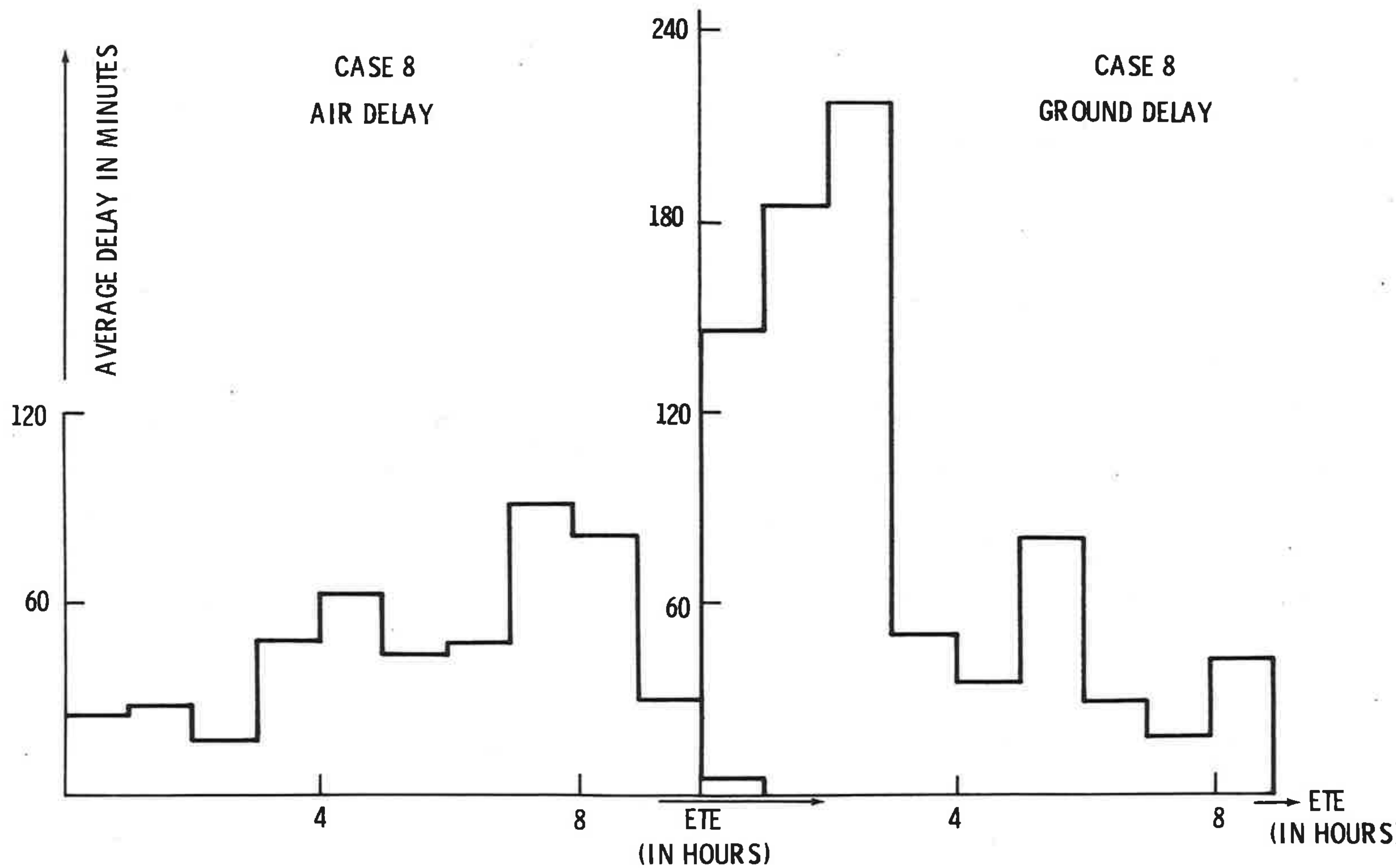

Figure 25. Average Delay vs. ETE for JFK, Conditions of Case 8 of Table 9

The distribution of delays as a function of ETE is shown in Figure 25, to be compared with the distribution for actual events on February 5 in Figure 20. The average delays would have been noticeably reduced, the peak dropping from 180 minutes to about 90 minutes. It will be noticed that delays for ETE's less than 180 minutes do not average zero, even though the New York air delay parameter was set to 0 hours, for flights with ETE's less than 180 minutes. This occurs because flights with ETE's greater than 180 minutes were not ground held in case 8, and arrived earlier relative to their landing slots than those that were held. The result is that they interchanged landing slots with the flights under AFCP (because of FCFS). Thus the AFCP flights landed somewhat later, and the non-AFCP flights somewhat sooner, than the ATA's and PTA's would indicate. This natural equalization process may be allowed for in any reduced notification scheme.

The conclusion to be drawn from these cases, then, is that a reduced notification time, continuous issuance of allocations and a simple-minded prediction scheme would have significantly improved AFCP effectiveness at both JFK and LGA on February 5.

SIMULATION STUDY

INTRODUCTION

This section is concerned with the application of digital computer simulation techniques as an aid in evaluating the February 5, 1971 case study and in deepening the understanding of AFCP effectiveness. After discussing the reasons for undertaking the simulation of AFCP, the chapter will briefly outline the scope, design, and constraints of the developed simulation. The real world data used in the simulation is presented, followed by a discussion of outputs. Validation results are then presented which show that the simulation is accurate enough to reliably model AFCP operations. At this point the chapter addresses the question of what happened on February 5th. Following these observations, several AFCP parameters are examined with the aid of numerous simulation runs and the chapter concludes with a brief review of the simulation-aided findings.

SIMULATION APPROACH

In the evaluation of the AFCP operations on February 5, 1971, need arises to understand what happened throughout that day. Equally important is the need to understand what would have happened if things had been different. Questions like, what would have happened if AFCP were not implemented that day? Or, how would the traffic situation change if the landing capacities had been different, the allocations had been applied rigidly, the "first 15 minute" rule had been eliminated, the AFCP cancellation time had been extended? What effect did the weather have regarding the traffic demands? There are many more questions of this kind which if answered would aid significantly in the evaluation of AFCP in theory and in practice and point the direction for improvements in ATC flow control techniques. These questions are quite varied and without some computational aid defy human solution because of the technical complexity, scope and detail required to calculate the effects in today's ATC system. Simulation on digital computers best provides this aid.

The simulation approach fulfills two important functional requirements. First, it can be used to generate and study a large number of cases. Since AFCP has been used so infrequently, even if data were available for the days when it was used, there would probably not be enough cases to allow a comprehensive evaluation of AFCP. (That is, to see how it performs under various conditions.) Secondly, controlled experiments can be performed with a simulator but not in the real world. For example, assume that the aim is to determine the effectiveness of the 15-minute rule. If AFCP were used twice, once with and once without using this rule, it would be difficult, if not impossible, to decide which differences between traffic patterns on the two days were due to the suspension of the rule and which were due to other factors. Using a simulator, a given set of conditions can be exactly reproduced - i.e., the same traffic, same quotas, and same airport capacities - the only difference being the use or non-use of the 15-minute rule. Any differences in results could thus be attributed to the 15-minute rule. In general, the importance of a factor can be studied by systematically varying it in a number of otherwise identical runs.

Some caution was needed in employing simulation techniques for this project. It was recognized that in using a model of the real world system, the model only approximates the complex interactions between aircraft, controllers and ARTCC's, The model cannot be expected exactly to match the real system. Recognizing this, the simulation was used to make comparisons and to develop a qualitative understanding rather than to predict detailed events. Care was taken to avoid sophistications that improve the precision of the simulation beyond the level needed for the study, permitted by the assumption of the models, or justified by the accuracy of the data.

THE "VAST" SIMULATOR

A previously developed program, the Versatile ATC Simulation (VAST), was employed for the task because it could be modified readily to incorporate the Advanced Flow Control Procedures. As an aid to understanding the operation of VAST in modeling AFCP, this subsection will trace the simulation of a flight step by step.

1. Setting Up - First a flight's identification (e.g., EA 24), origin, destination, first fix in the New York Center, aircraft type, and planned flight speed are read in from the file of cards prepared by NAFEC, followed by the PTD and PTA from the OAG. Then the estimated time enroute and the maximum length of time the aircraft is willing to hold before diverting* are calculated, and a cruise altitude is assigned as follows: Within the constraints that no aircraft be assigned an altitude below 10,000 feet

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* Diversion time tolerances were determined in two ways. If the aircraft actually diverted on February 5th, the time was that of actual wait before diverting, but not less than 20 minutes. All other aircraft were given a random time uniformly distributed between two and four hours.

or above the ceiling for its type, short flights (up to an hour) are given altitudes up to 25,000 feet proportional to their ETEs, and long flights are given random altitudes between 25,000 feet and their ceiling.

2. Takeoff - At its PTD, the aircraft asks for clearance to take off. If AFCP are in effect at its PTA, the remaining allocations for the hour of arrival are checked. If there is an available allocation, the aircraft is assigned whatever delay is necessitated by the 15 minute rule if the rule is in effect. If there is no available allocation, the next hour is checked. This look-ahead continues for at most four hours, until AFCP go out of effect or there is an available allocation. The aircraft is then assigned the appropriate delays, i.e., it is scheduled to arrive at the beginning of the available hour or 15 minutes into the hour if that rule is in effect. If no slot can be found, the aircraft is either cancelled or an exception is made and no delay is given. (This decision is made randomly according to a specified probability.) The weather is also considered in assigning delays, a specific delay being associated with each type of weather (rain, fog, thunderstorms, and snow).* The aircraft must wait whichever amount of time is greater - the AFCP delay or the weather delay. After waiting its assigned time, the aircraft is cleared to take off. It taxis (gate time to wheels-up time ranges from seven to ten minutes) and takes off.

3. Enroute - After takeoff the aircraft flies line-of-sight to its first fix in New York, checking in periodically with each ARTCC it traverses. During its climb, it observes the climb rate and climb speed characteristic of its aircraft type as well as the speed limit of 250 knots below 10,000 feet. When it reaches its cruise altitude, it accelerates to its cruise speed. At center boundaries, aircraft are handed over subject to handover rate restrictions (e.g., miles-in trail restrictions), if any. If a thunderstorm is encountered, the aircraft flies around it, resuming its line-of-sight path as soon as it is clear of the storm.

4. Arrival in New York - When the aircraft arrives at its first fix in New York, a check is made to see whether a landing slot is available. If so, the aircraft is cleared to land and begins its landing approach via the nearest hold fix. If no slot is available,

* Areas of weather were input at 1400Z during the simulation and automatically moved in a northeasterly direction at 20 knots until the end of the simulation. These weather areas produced a 30 minute take-off delay in the Golden Triangle (New York, Chicago, Washington) part of the United States.

the holding time is estimated based on landing capacity and the number of aircraft already holding. If the estimated hold exceeds the aircraft's tolerance (as calculated earlier), the aircraft diverts and is dropped from the simulation (since we are only modeling arrivals at JFK and LGA). If the aircraft can hold, it is placed on a list of aircraft waiting for clearance and flies to the nearest hold fix at the next available altitude. Aircraft on the list are cleared on a first-come-first-served basis as landing slots become available. Within 90 miles of their destination, aircraft descend according to a nominal glide slope. At about 42 miles they begin decelerating in preparation for their descent below 10,00 feet, where the speed limit is 250 knots.

5. Landing - If the aircraft arrives at its hold fix without having been cleared to land, it waits there until a slot becomes available. Once it has clearance, it begins to follow an approach route to the terminal, observing speed and altitude limits for each route leg. (Standard Metroplex approach routes for runway 22 at both JFK and LGA were used.) An aircraft is considered landed when it is one mile from the runway.

6. Constraints - There are limits to the numbers of peak airborne aircraft, VORTAC's, routes, aircraft types, AFCP terminals and terminal holding points. But these limits easily permit the complete simulation of the JFK and LGA traffic situation on February 5th. Several features were not incorporated into VAST because the expected added precision was not required for this study. These features were individual aircraft separation by ground controllers, spherical earth corrections and winds aloft effects.

INPUTS

The major inputs to VAST are summarized in Table 12. Since the aircraft files, based on the flight strips prepared by NAFEC are a very important input to the simulation, it is well to review the data content. Three flight strips were required for each aircraft although often less than three were found. First was the departure strip containing the actual time of departure, the ETE, and the planned flight speed. The second strip was the aircraft's first fix in the NYARTCC. This strip provides the identification and time of arrival at the first fix in the NYARTCC. The last strip was the landing (final) strip which showed the actual time of landing at JFK or LGA. TSC added to the flight strip data the airline guide PTD and PTA. Those aircraft that air filed were identified as such. It must be noted that these 700 data cards do not include aircraft which cancelled or otherwise did not fly that day. These cards were used by the simulation in generating the same traffic demand which existed during that 24-hour period.

TABLE 12

DATA INPUTS TO VAST

Geographical:

- ARTCC boundaries (mapped in with graphic tablet)
- Terminals (airports) - latitudes and longitudes
- VORTAC's and Fixes - latitudes and longitudes
- Holding Fixes - latitudes, longitudes and available altitudes
- Routes and Approach Paths - latitudes, longitudes, altitude restrictions, and speed restrictions by leg
- Weather areas (mapped in at run time with graphic tablet)

Procedural:

- AFCP Allocations (by ARTCC, hour, and AFCP terminal as reconstructed in Section IV from available swapping records)
- AFCP Implementation Period
- 15 Minute Rule Criteria
- Allocation Exception Criteria

February 5 Traffic Data:

- Landing capacities for AFCP Terminals (from Table 16, Appendix C, or as hypothesized)
- Aircraft schedule file, based on flight strips, containing
  - Aircraft ID
  - PTD (optional wheels up or air file times)
  - Origin Terminal
  - Destination Terminal
  - ETE
  - Planned Flight Speed
  - First Fix in NY ARTCC
  - Aircraft type

Aircraft Performance Parameters for Each Type:

- Cruise Speed
- Climb Speed
- Climb Rate
- Approach Speed
- Altitude Ceiling

OUTPUTS

The data produced by VAST are output onto disc storage files. There are two types: General totals and averages for the entire system (Table 13), recorded every 10 minutes of real time; and histories for each aircraft, (Table 14) recorded at the end of the run.

VAST also produces system level graphs* up to a 24-hour period by AFCP airport (JFK and LGA) for any or all of the 25 different kinds of data listed in Table 13. Further, it is possible to plot the data either cumulatively or as an instantaneous time related quantity (all of the AFCP simulation runs used a simulated 10-minute interval in recording the time related data). In addition, these graphs can be rapidly drawn on a CRT storage scope for viewing or can be produced in hard copy on a calcomp plotter. A valuable feature of the graphical output is the ability to combine the curves from several different simulations onto the same coordinates. Many of the graphs presented in this section exploit this feature to contrast various results. When the need arises, because of the complete records (disc files), a report for each aircraft can be produced containing the different kinds of information listed in Table 14. In fact, comparative listings of the flight histories for each aircraft from different simulation runs proved very useful in this study, particularly in the validation of the model to be discussed in the next subsection.

VAST also provides a dynamic display of the simulated events. Starting with a display of the entire modeled airspace (CONUS) it is possible to zoom in on any area with corresponding improvements in the resolution of the traffic movement, (each aircraft is represented by a 3 dot trace). Light pen techniques are employed allowing the identification, speed, altitude and clearance status of any aircraft to be readily obtained. It was therefore possible to recreate visually the aircraft movement for February 5th and observe the AFCP traffic problems such as traffic into a center, holding aircraft, diversions, and landing sequences.

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* Note : The graphs presented in this section are computer generated. The vertical coordinate presents values for those data shown in the associated legend and described in Table 13. The horizontal coordinate is always Greenwich Mean Time (GMT). Please note the use of automatic scaling shows 0100 GMT as 250.0 ($x10^1$). These GMT scales represent the EST time period from 11 p.m, February 4, 1971 to 11 p.m. February 5.

TABLE 13

SYSTEM DATA RECORDED BY VAST EACH 10 MINUTES OF SIMULATED TIME FOR EACH AFCP AIRPORT

	Description of Data	Alpha-Code Used in Computer Generated Graphs in this Section
1.	Number of aircraft AFCP ground delayed	#AGDL
2.	Average AFCP ground delay	AVDEL (#AGDL)
3.	Number of aircraft 15 min. rule ground delayed	#15DL
4.	Average 15 min. rule delay	AVDEL (#15DL)
5.	Number of weather delayed aircraft (ground)	#OGDL
6.	Average weather delay	AVDEL (#OGDL)
7.	Total number of ground delayed aircraft, all causes	#G-HD
8.	Number of aircraft given exception from AFCP delay	#G-EX
9.	Number of aircraft cancelling on ground due to AFCP	#G-CN
10.	Number of aircraft cleared for take off	#CLTO
11.	Number of aircraft enroute to NY ARTCC (ZNY)	#ENR
12.	Number of aircraft arriving at first fix in ZNY	#ANY
13.	Number of aircraft air filing	#AFIL
14.	Number of aircraft given AFCP air file exception	#A-EX
15.	Number of aircraft landing slots (capacity)	#CAPC
16.	Number of aircraft cleared to land	#CLLD
17.	Number of aircraft going to hold	#HOLD
18.	Number of aircraft that decided to divert	#DIVT
19.	Average anticipated delays for diverted aircraft	AVDEL (#DIVT)
20.	Number of aircraft holding at position 1	#HD-1
21.	Number of aircraft holding at position 2	#HD-2
22.	Number of aircraft holding at position 3	#HD-3
23.	Total number of aircraft holding in air	#A-HD
24.	Average delay for air delayed aircraft	AVDEL (#A-HD)
25.	Number of aircraft landed	#LND

TABLE 14

INDIVIDUAL AIRCRAFT DATA RECORDED BY VAST

Description of Data

1. Aircraft identification code
2. Planned time of departure (PTD)
3. Origin airport, or air file fix code
4. First fix in the NY ARTCC (code)
5. Destination airport code
6. Aircraft type
7. Planned cruise altitude
8. Planned cruise speed
9. Estimated time enroute (ETE)
10. Actual take off time
11. AFCP ground delay
12. Weather departure delay
13. Time of arrival at first fix in NY ARTCC
14. Air delay at destination
15. Projected air delay if decided to divert
16. Landing time
17. Landing airport (different when diverted)

VALIDATION OF THE VAST SIMULATION

Precision of Real World Data

In analyzing the precision of any simulator, it is necessary to understand the precision of the real world data used to check the simulator. The data extracted from 400,000 flight strips was the best available but falls short of ideal data. The bulk of the flight strips did not contain annotated updates on recorded times. The accuracy of the times estimated by the ARTCC computers, which print the strips about 30 minutes before the event, is subject to error distributions of several minutes; and when traffic is heavy as it was on the 5th because of the enroute delays, the printed flight strips can be 10 or 20 minutes in error for a significant number of aircraft. Not only were errors of this kind expected in the extracted flight strip data but also many data estimates would have to be made for missing times on flight strips and even missing flight strips themselves. By agreement, NAFEC in reducing the data identified all estimates on the IBM cards. The difficulty in reducing the data from 400,000 strips and the incompleteness of the flight strip data is observed from the fact that out of the 700 cards (inbound JFK and LGA traffic) over 90 percent contained one or more time estimates for the three important events: wheels up, arrival at first fix in the New York ARTCC, and wheels down.

Levels of Correlation Employed

The standard procedure for validating a simulation is to check the statistical results against the statistical data of the real world, that is to say to check the relationships at a total system level. It is highly unlikely, because of the simulated decisions and approximations used in simulating events, that individual entities (such as aircraft) correlate with the real world; and indeed this individual correlation is not needed for most simulations. In this AFCP study, investigating demand loading, system effects, and efficiency measures, it is not necessary nor critical to the results that there be an exact correlation, aircraft by aircraft. For example, a few seconds difference in arrival time at a hold fix makes a difference in which aircraft holds the longer, yet the net effect on system air delay measures is exactly the same. In fact a slight difference in enroute time, coupled with heavy demand and low landing rates, can produce differences in individual aircraft histories measured in hours.

Despite the heuristics and approximations employed by VAST, the inherent inaccuracies in flight strips, and the large quantity of estimated times in the real world data, there was a good correlation on an individual aircraft basis and an excellent match on the system level.

Correlations at Level of Individual Aircraft

The correlation for individual aircraft was obtained by simulating the February 5th traffic using the actual, (NAFEC data), wheels up time as the simulated take-off time. The aircraft were then modeled through the climb and cruise phases until they reached the first fix in the New York ARTCC. The simulated time of arrival at this first fix was then compared with the actual recorded time (from the NAFEC cards). The resulting agreement between the two first fix times is listed in the following tabulation:

Percent of aircraft vs. time agreement*

44% agreed within 4 minutes accuracy
71% agreed within 10 minutes accuracy
86% agreed within 20 minutes accuracy

The correlation for the flight phase from the first fix through the hold (delaying in the air as necessary) and along the appropriate landing approach path was accomplished by simulating the flights from the first fix to the time of landing (including air delays) and then comparing the simulated landing time with the actual landing time (from NAFEC data). The following tabulation presents the results of comparing the landing times; also shown is the percentage of aircraft in each group that were held in the air and the peak air delay within that group:

Percent of aircraft vs. time agreement*	From Simulation Results: Percent of Aircraft that held in air.	From Simulation Results: Peak Air Delay
19% agreed within 4 minutes accuracy	56%	41 min.
42% agreed within 10 minutes accuracy	76%	87 min.
69% agreed within 20 minutes accuracy	69%	87 min.

* Percentages are based on only those aircraft for which complete flight strip information was found, i.e., aircraft with NAFEC time estimates excluded.

In addition to the correlations presented above, the assumptions and approximations used in modeling each aircraft's flight phase can be seen to be reasonable from two selected examples, comparing the simulation results with the real world flight history. Although several of the simulated flights matched exactly to the real world flight times, these would not represent the typical match. In an attempt to select objectively, the longest simulated flight and a reasonable medium range (2 hour ETE) flight were chosen. The longest flight, AA 164, flying from Hawaii to JFK took 8 hours and 45 minutes to arrive at the first fix in the New York ARTCC; the simulation of AA 164 took 8 hours and 48 minutes for this same flight segment. A typical flight in the two hour range, PA 206, flew from Nassau, arrived at the first fix within 6 minutes of actual, held for 69 minutes because of JFK traffic loads and landed within 6 minutes of its actual wheels down time.

Correlation at a Statistical or System Level

Because of the correlation shown in the above tables, one would expect a good correlation at the system level and indeed that is the case. Most important at the system level in measuring the effectiveness of AFCP is the quantity and distribution of air delays caused by the excess traffic demand and the restricted landing capacities. Shown in Figure 26 are the comparative results of the simulated air holds (#A-HD). The simulation run DTB228 (see legend on Figure 26) modeled the flights from takeoff (using the exact wheels up time recorded in NAFEC data) through landing. The simulation run DTB328 modeled the flights from the first fix (time at first fix from NAFEC data) through landing. This latter run was the best simulated match with the real world and is used throughout this section as a base of comparison representing the real world events. In addition, this run was required since specific air hold information was not recorded on the flight strips. Compare Figure 26 with Figures 16 and 17 which were derived manually using 30 minute averaging and estimates of normal flight path times. Figure 26 is more detailed (i.e., composed of continuous ten minute interval instantaneous counts of aircraft stacks) and the flight path times are individually modeled.

If one looks at the system on a cumulative basis as was done in Figures 14 and 15, it can be seen that the simulation-produced curves of Figure 27 agree with the corresponding manually derived results for each airport. The "#A NY" curves match the "available, without diversion curves" as do the "# LND" with the "actual" (landed). In addition, Figure 27 shows the curve for cleared to land (#CL LD) which aids in resolving the air delay magnitudes

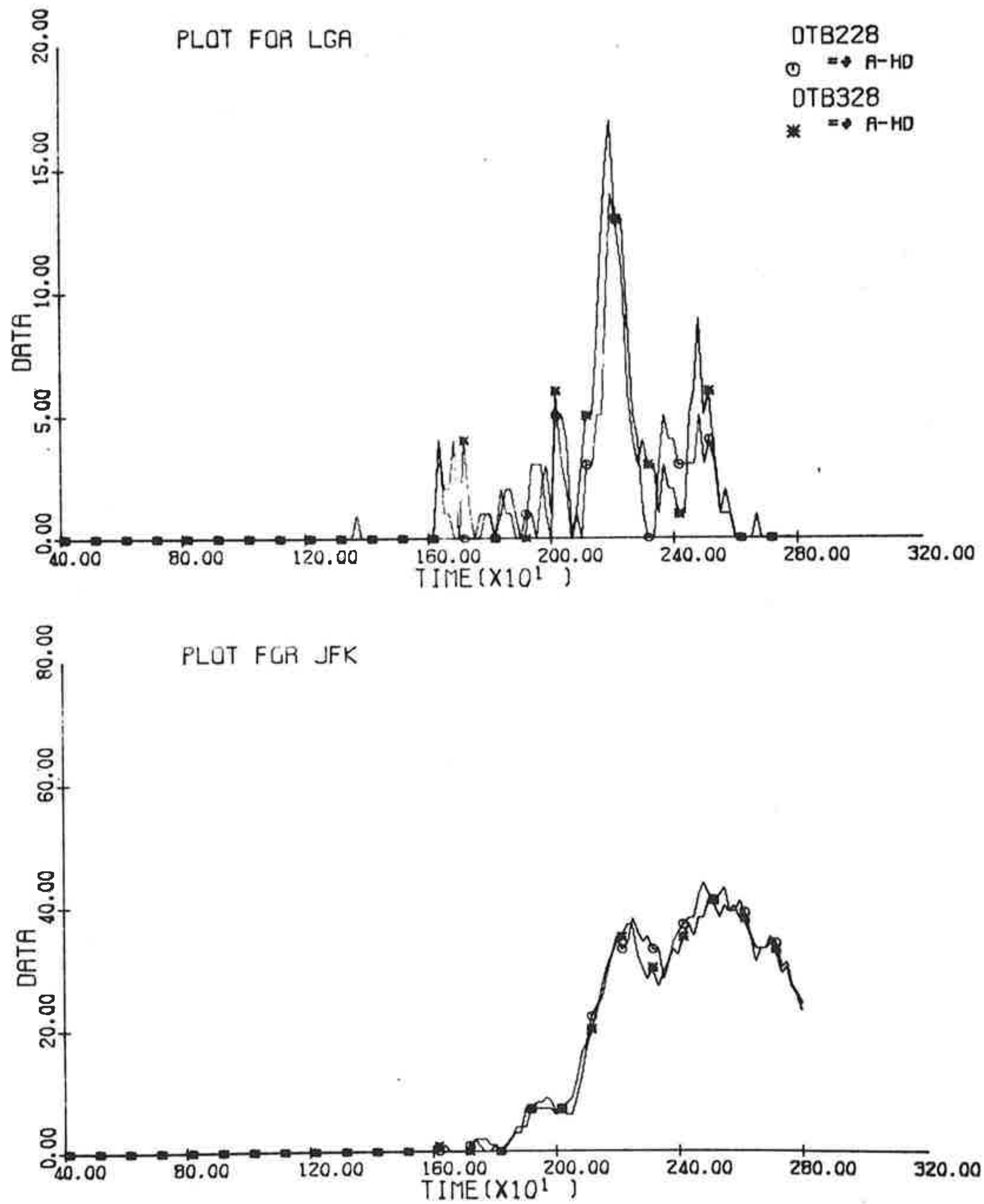

Figure 26. Number of Aircraft Holding, Simulated vs. "Actual".

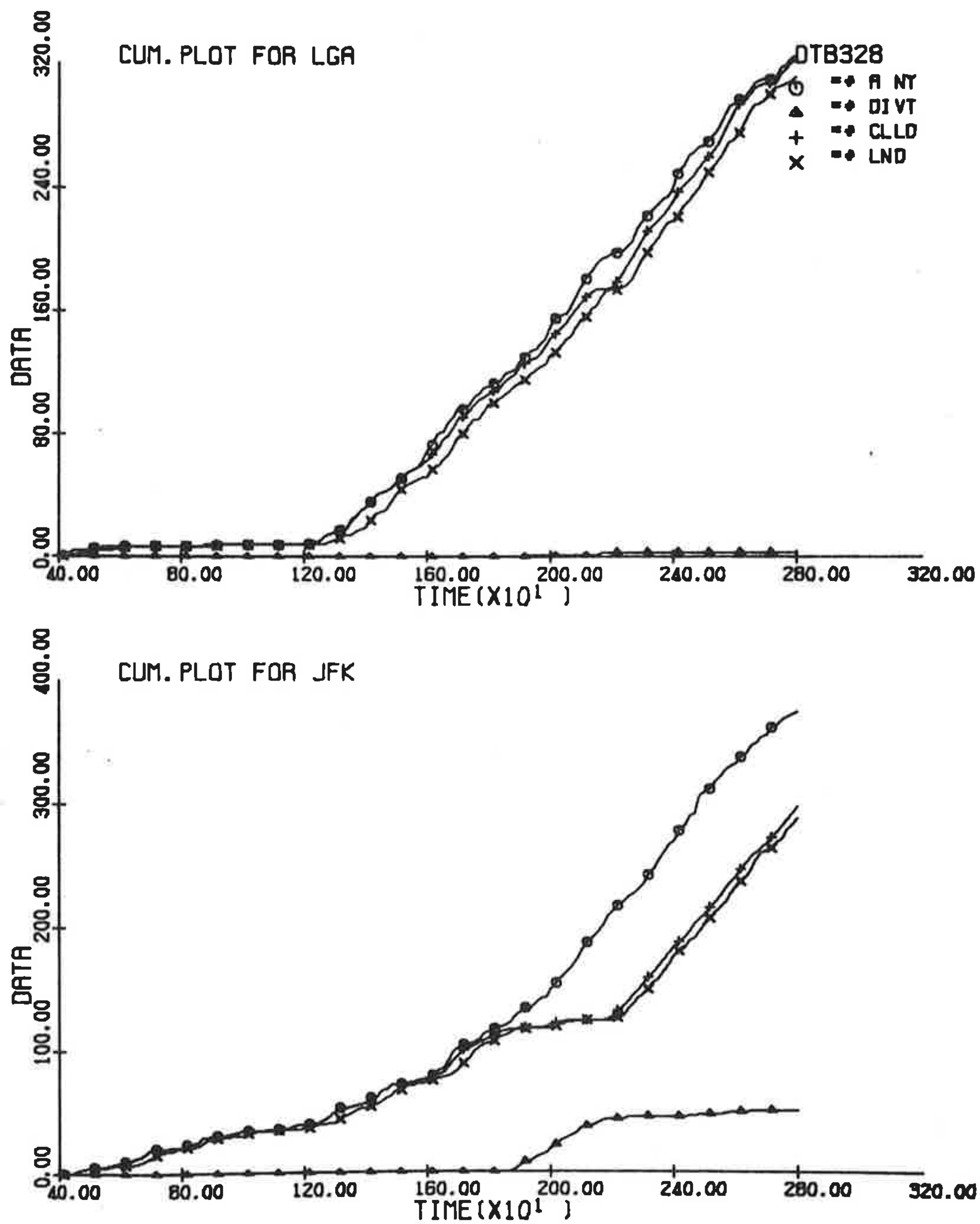

Figure 27. Cumulative Data From Simulated Actual Traffic

and quantities of aircraft. Further discussions of the significance of these curves follows in the simulation's view of what happened on the 5th.

The correlation of the two runs shown in Figure 26 along with the individual aircraft correlations and the numerous simulation results to be discussed in the remainder of this section, built a high confidence that VAST was accurate enough to reproduce the AFCP effects and to make comparative evaluations of AFCP under various hypothesized conditions.

VAST'S VIEW OF FEBRUARY 5th

In the previous sections of this report the events of February 5th have been reconstructed from the available data and presented de facto. With the aid of VAST and comparative graphs let us examine what happened in relation to what would have happened if the modified AFCP allocations, as reconstructed in the previous section had been applied in the presence of weather delays.

Effect of Simulated Allocations on Arrivals

Remembering that run DTB328 presents the results corresponding with the actual day, (referred to in the remainder of this chapter by the description, "actual") Figure 28 shows the first comparison. Cumulatively plotted in Figure 28 are the data from run DTB128, a simulation where all the aircraft were allowed to take off on schedule (i.e., PTD's, no AFCP operations) and there were no weather delays incurred. The curves show for each run the cumulative total number of aircraft that entered (arrived) the New York ARTCC during the day. These curves, in fact, give the demand loading produced in each run. Note the fact that the PTD simulation (RUN DTB128) does not have any period of implemented AFCP's, while the "actual" simulation (RUN DTB328), because it used the actual flight strip information must have in it all the actual AFCP effects as well as weather delays. There is a striking similarity in the demand curves with deviation occurring only during the late 2200 to 0100 GMT period. Before discussing this similarity, one more simulation run must be introduced. This is run DTAB28, (Figure 29), in which a weather delay of 30 minutes is added to the PTD's of RUN DTB128 at all the departure terminals in the "Golden Triangle" region for the appropriate time period derived from the actual data. Also the simulated takeoffs were requested by the modified AFCP allocations as reconstructed in the previous section. They were applied from 1800 until 2700 hours and were then cancelled at 0000 hours (approximately the time of actual cancellation on February 5th). Figure 30 presents the results (each figure is compared to the actuals from run DTB328). A substantial

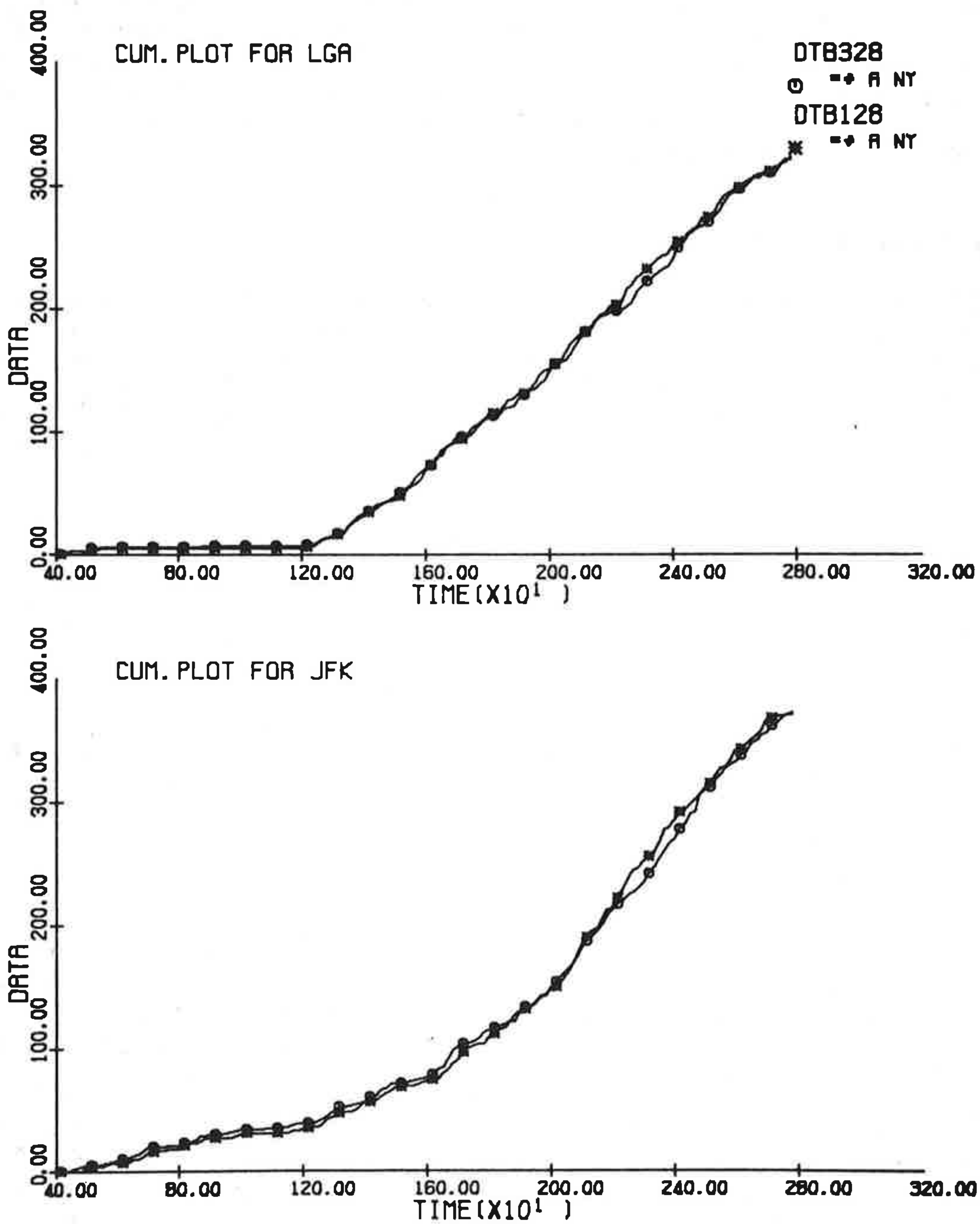

Figure 28. Arrivals at the New York ARTCC, "Actuals" vs. PTD's

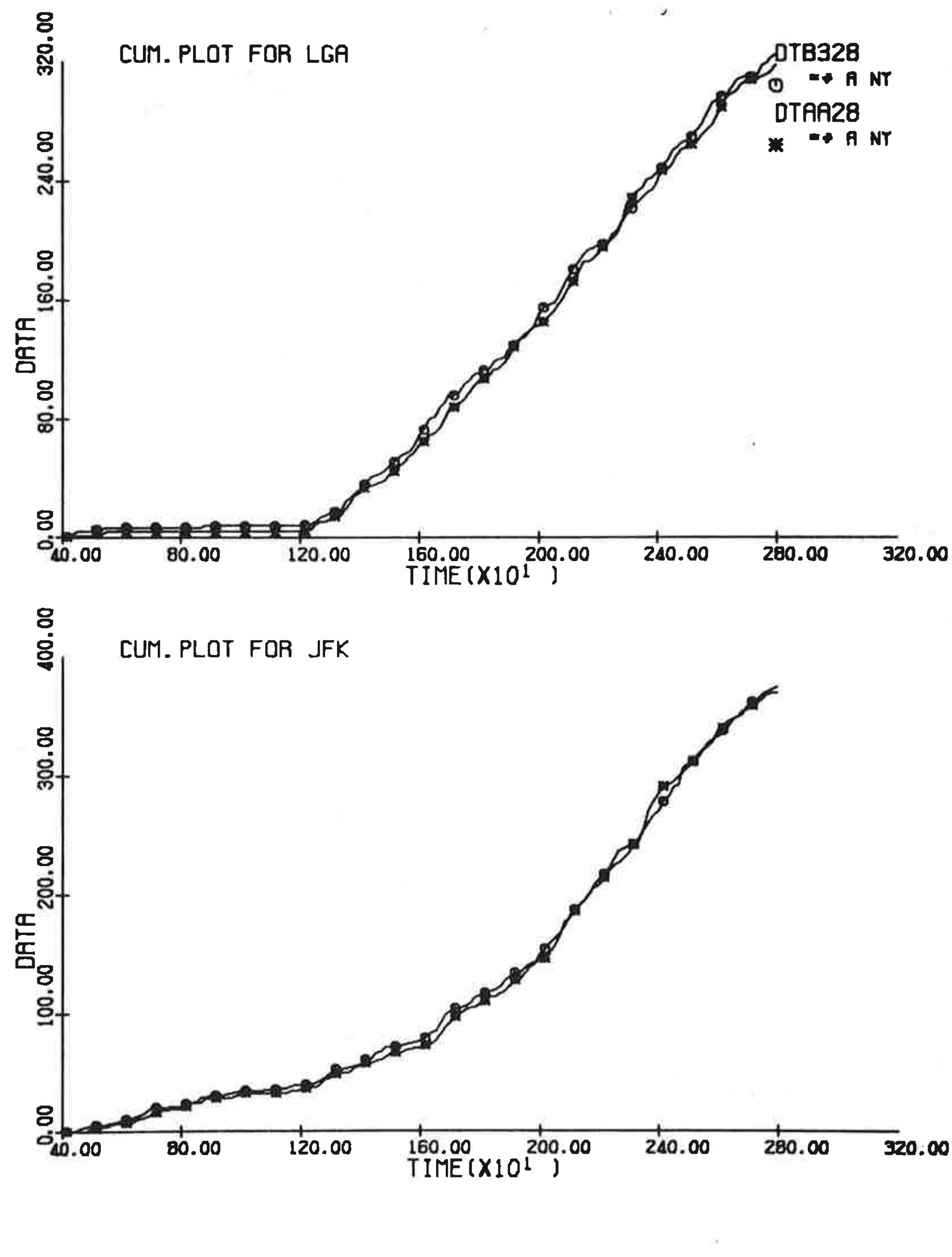

Figure 29. Arrivals at the New York ARTCC, "Actuals" vs. PTD's with Weather Delays

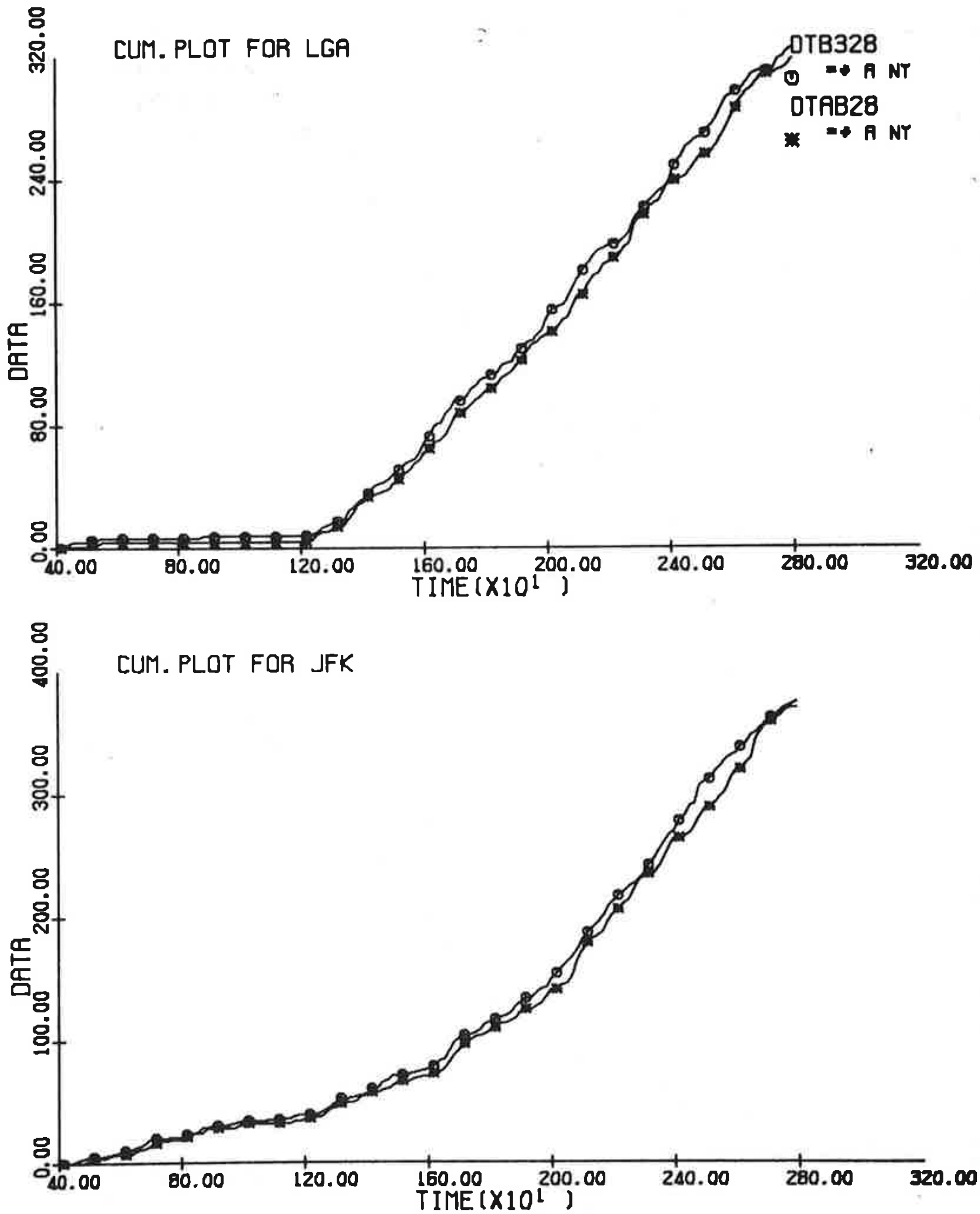

Figure 30. Arrivals at the New York ARTCC, "Actual" vs. AFCP with Weather Delays

reduction in the demand can be seen in Figure 30 from roughly 1800 to 2600 GMT. Figures 28 through 30 show that both airports exhibit the same relationships (noting that the computer-generated vertical scaling on Figure 28 is different than 29 and 30).

What happened that day? Why the apparent reduction in the simulated vs. actual AFCP arrivals? Acknowledging that the simulation can only approximate the real world, a check of the simulations results verified that there were no errors great enough to cause the observed effects. More likely, what is seen as reduced arrivals in the simulated AFCP run is the combination of several factors. It is known that exceptions to the AFCP allocations were made by the New York ARTCC, the bulk of which were prior to the JFK closure at 2100 GMT. Some of these exceptions were recorded, but it is possible that many were not. Not to be overlooked is the fact that many of the ARTCC's, particularly those in the "Golden Triangle" were encountering serious traffic problems due to the bad weather and concentrated on their own serious problems which may have overridden strict adherence to AFCP. In summary, the data from these simulation runs indicate that strict adherence to the AFCP allocations of February 5th would have produced a somewhat lower arrival curve than actually occurred.

Effect of Simulated Allocations on Air Delays

Continuing the comparisons, what happens to the aircraft arriving at these different demand levels? Depending upon the landing rates the arriving aircraft can be cleared for landing or delayed in the air and if the air delays are excessive possibly divert to an alternate terminal. Looking at Figure 31 we can study the traffic disposition for the actual day (RUN DTB328). Cumulatively plotted along with the arrivals in the New York ARTCC are the number of diversions, the number cleared for landing and number landed.

If one takes a vertical time slice anywhere along the horizontal coordinate, it is possible to find the number of aircraft that are holding (or on their way to a hold position) when the demand exceeds the landing capacity. To aid in doing this, we have drawn in an added curve for JFK in Figure 31, labelled NET ARRIVALS. This curve is the result of subtracting total diverted aircraft from the total number that arrived at the New York ARTCC. The vertical difference between this curve and the cleared to land curve (#CL LD) represents the quantity of aircraft being air delayed. The vertical difference between the cleared-to-land and landing curves gives the number of aircraft currently on their landing approach. If one looks at the horizontal differences

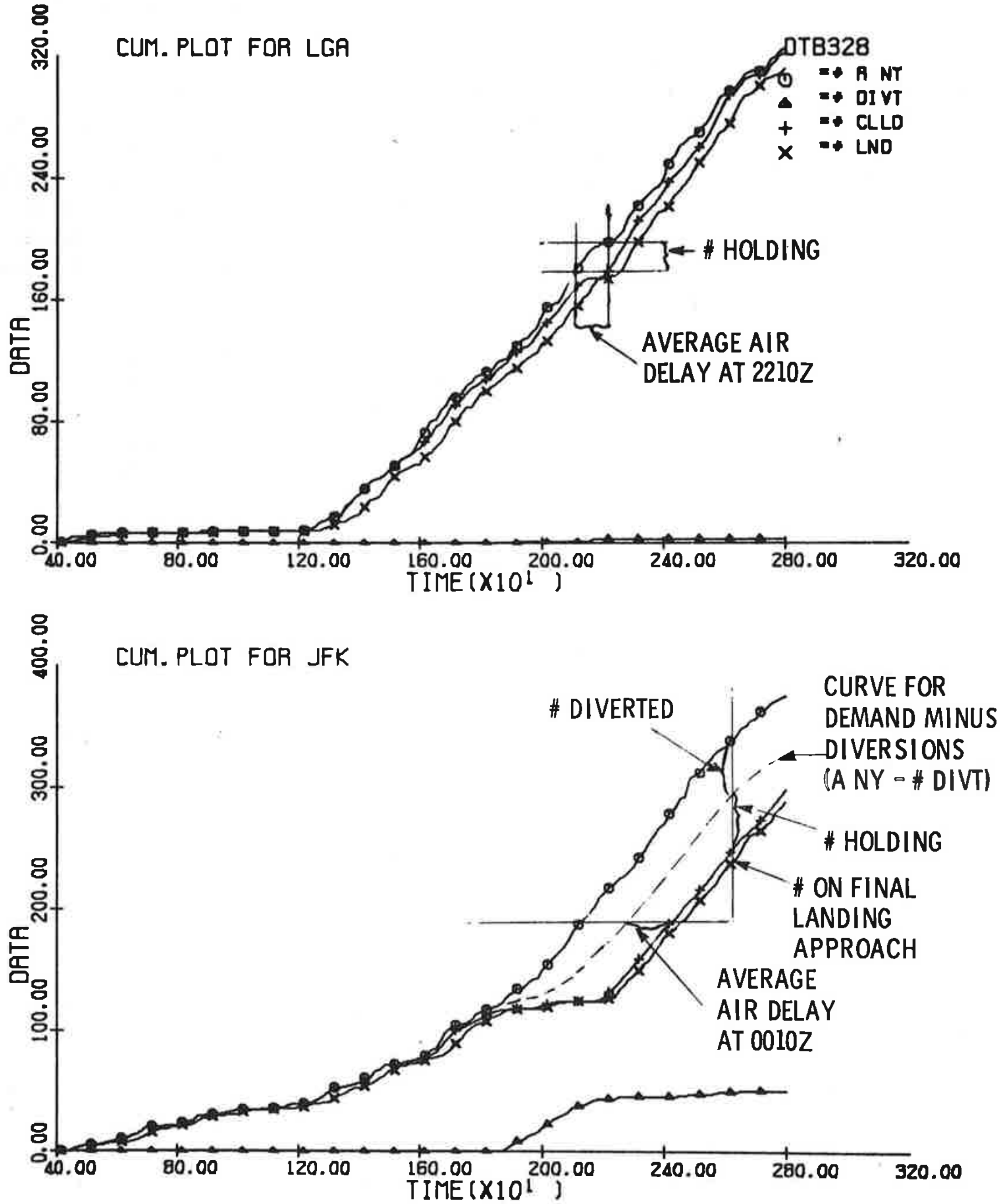

Figure 31. Actual Day Traffic Disposition (with annotated description)

between curves, it is possible to determine the time between events for an individual flight. For example the drawn-in curve compared to the cleared-to-land curve gives the air delay at the time of clearing.

Figure 31, therefore, gives a clear overview of the actual events of the entire day, as represented by the simulation. This can now be compared with the simulated results of strict application of AFCP allocations shown in Figure 32, RUN DTAB28. This figure shows a continuous reduction of demand arrivals at New York as well as an associated reduction in diversions due to the shorter air delays. Figure 33 shows the effect on the air delays of the reduced arrivals and reduced diversions that would have occurred. For JFK it appears that strict adherence to AFCP allocations would have: slightly improved the air delay situation; would have produced arrival waves, as evident from the step-like arrival curve; would have maintained full utilization of landing capacities; would have reduced the JFK diversions; and of necessity would have ground-delayed more aircraft in achieving these results. (These conclusions are based on the actual landing rates achieved that day. Later we will investigate what would have happened if the original AFCP landing capacity estimates had actually been achieved.) The result of strict AFCP observance for LGA is not as distinctive, because landing capacities for LGA were not as distinctive and landing capacities for LGA kept up with the arrival rate (reference Figure 32). Only short delays and small stacks occurred at LGA.

Effect of Simulated Allocations on Ground Delays

We have looked at the demand and at the New York air delay problems. What happened concerning the ground delays required by strict AFCP observance? It was not possible to determine AFCP ground delays from the flight strips because these delays were mixed in with the bad weather and gate-to-wheels-up delays so common on February 5th. The primary AFCP ground delay information source must therefore be the VAST simulation. The simulation shows the magnitude of these ground delays for the run where the modified allocations were ideally observed (DTAB28). Figure 34 shows for JFK and LGA the cumulative number of aircraft receiving an AFCP ground delay (consistent with ARTCC quota allocations) and the numbers of aircraft receiving small delays (1 to 15 minutes) because of the first 15 minute rule.* Also plotted are the

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* Reviewing this rule briefly, the ARTCC's adjust (delay) departure times so as to allow no arrivals during the first 15 minutes of an AFCP hour.

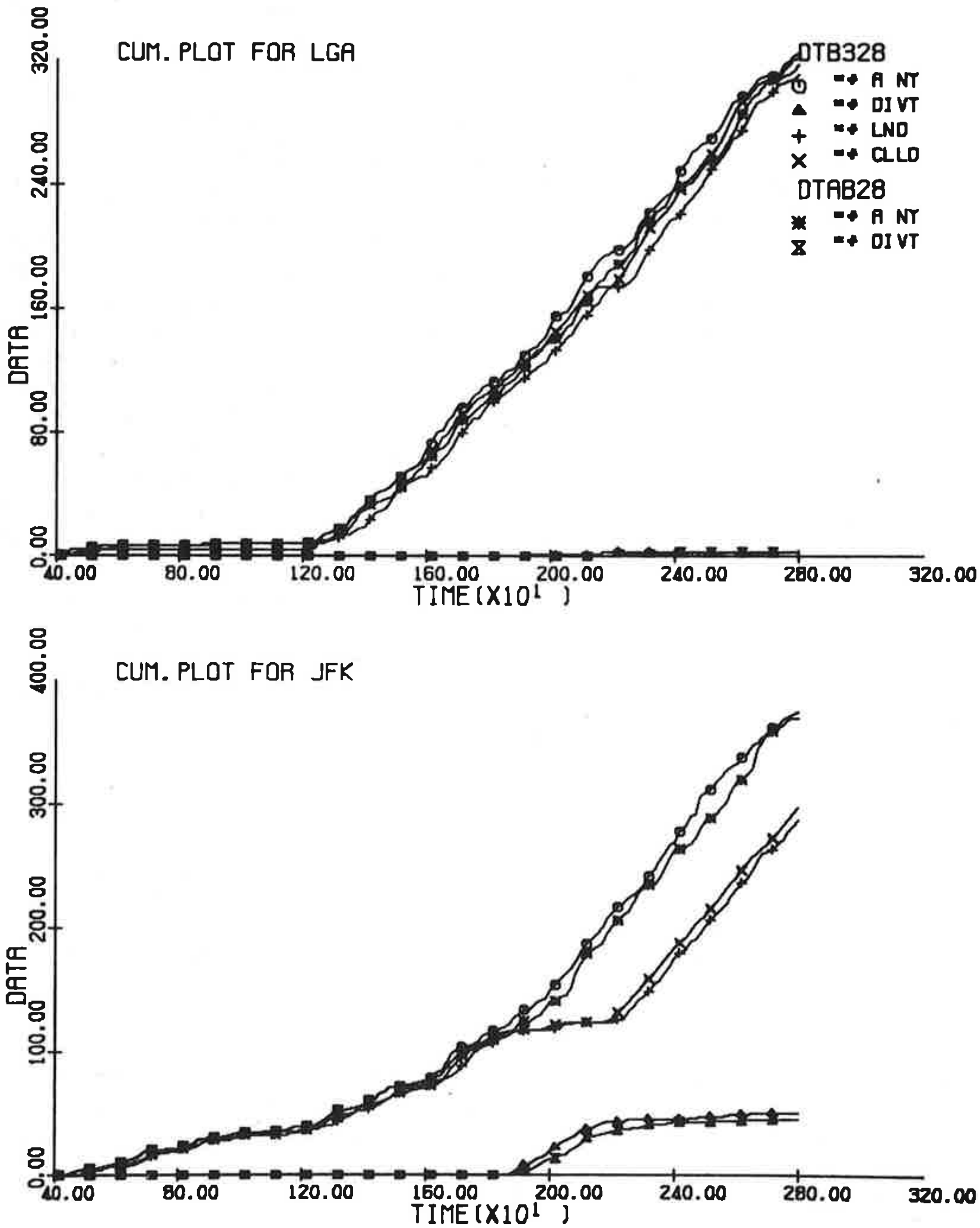

Figure 32. System Comparison of Actual vs. Strict AFCP Observance

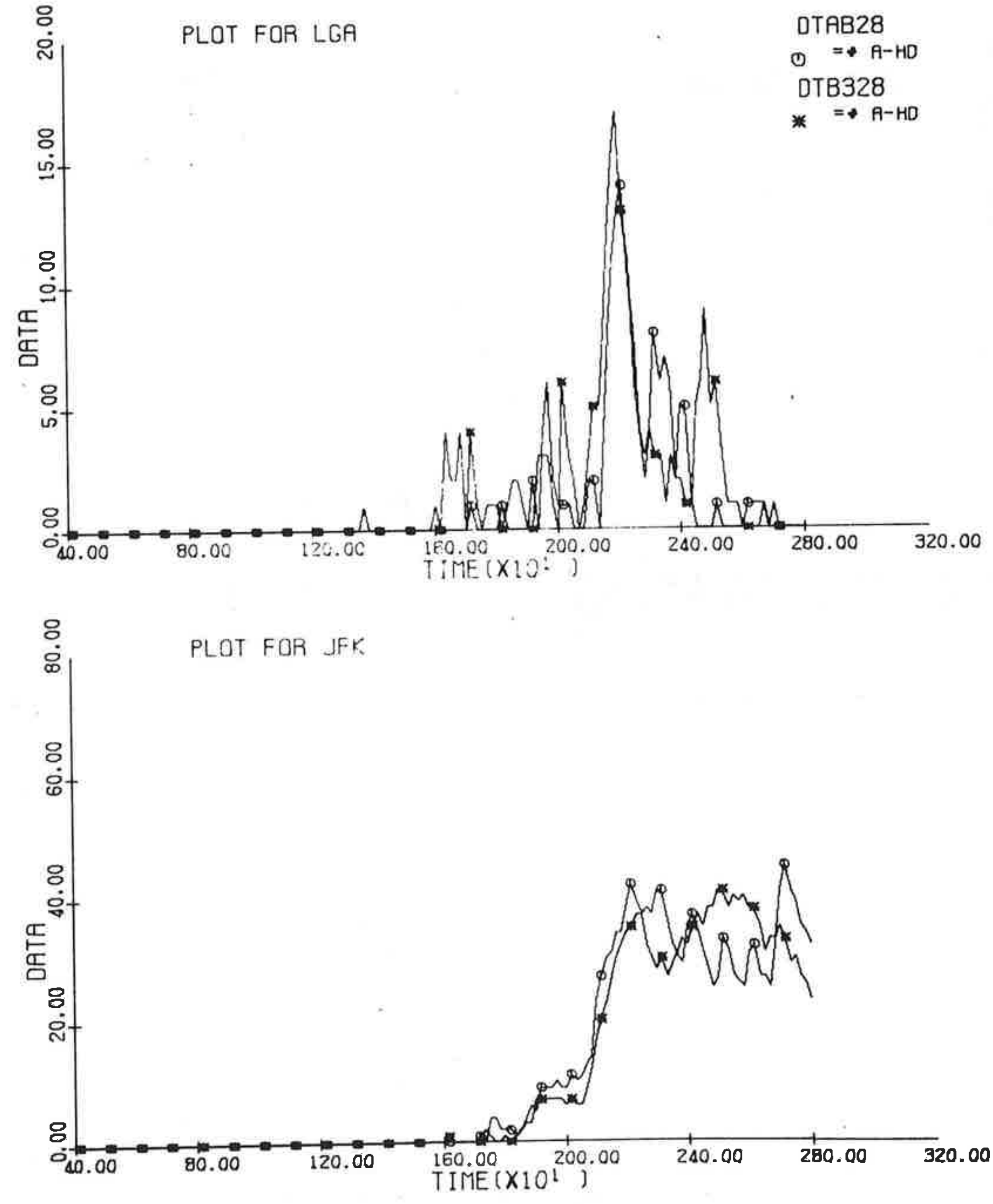

Figure 33. Air Delay History for Actual vs. Strict AFCP Observance

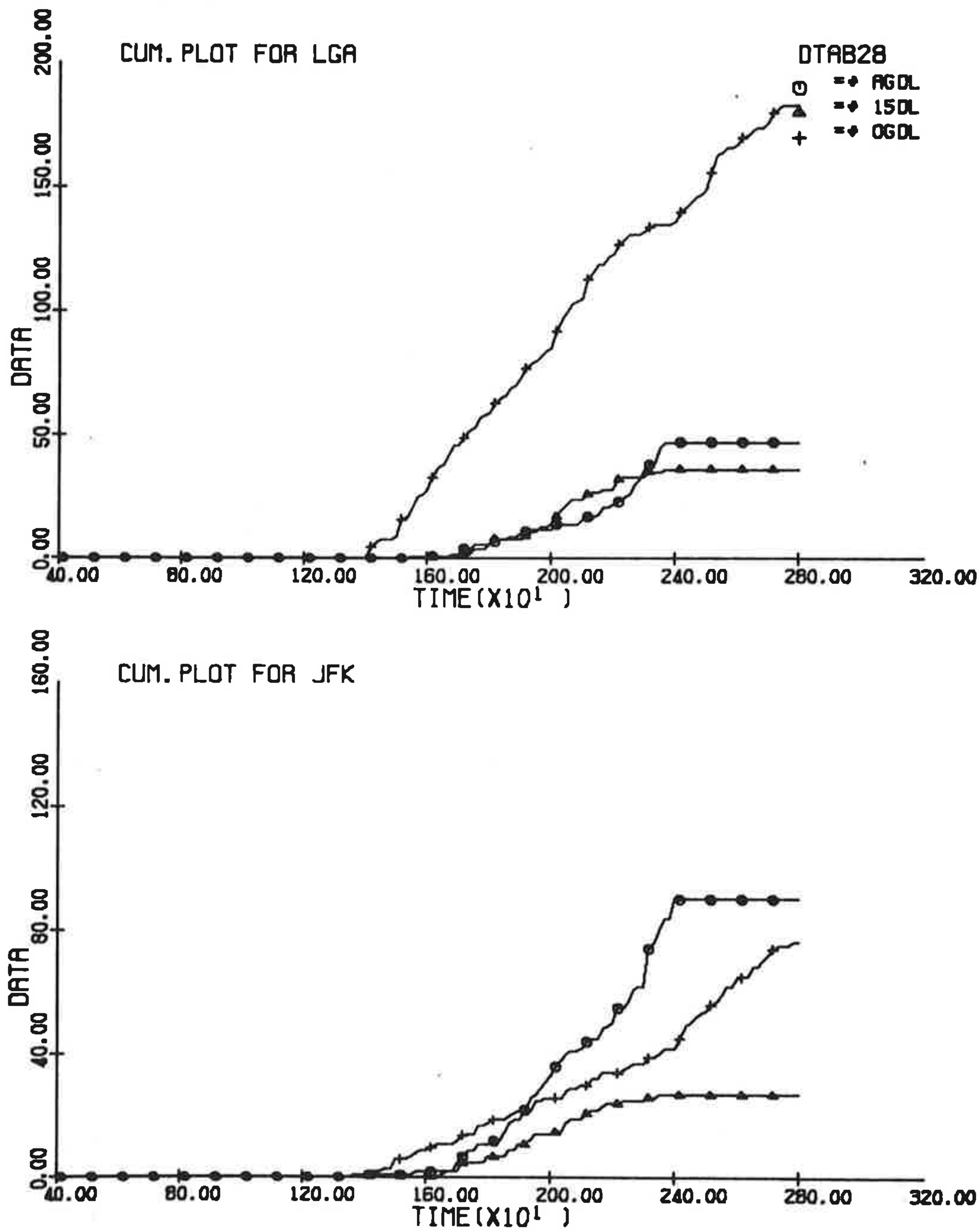

Figure 34. System Ground Delays for AFCP and Weather Simulation

numbers of aircraft delayed by the simulated bad weather in the "Golden Triangle" region. About 150 aircraft (both JFK and LGA) would be affected due to AFCP ground delays. Using the results from a run without weather (DTAD28), we can see the instantaneous ground holding situation (see Figure 35) for AFCP and for AFCP plus weather ground holds. At 2400 GMT, for example, about 40 aircraft were delayed on the ground because of AFCP. These curves (Figures 34 and 35) are suggestive of the ATC administration work load involved in carrying out exact AFCP allocations as well as showing the scope of the AFCP ground delays.

Before leaving Figures 34 and 35, note the relative weather delays. One can see the substantial effect on LGA traffic in comparison to the minor effect on JFK traffic. In Figure 36 (run DTAB28 with weather and run DTAD28 without weather) this airport difference is easily seen in the demand and landing rates for LGA. Recognizing that the bulk of LGA's traffic comes from the "Golden Triangle" this effect is obvious. Considering the relative sensitivity of the LGA traffic to large area weather delays, it seems that the AFCP allocations for LGA (and for any AFCP terminal whose traffic is mostly short range), would be more accurate if weather departure delay predictions were considered in the AFCP allocation algorithms.

Summary of VAST's View of February 5

VAST's view of the 5th can be interpreted in the following manner. The actual arrivals of that day compare closely with those for a day on which most flights departed on their PTD's, except those arriving in a period from 2200Z to 0100Z. The size of the stacks for JFK would have been favorably reduced if fewer exceptions and stricter observance of AFCP allocations were applied to JFK traffic. Weather delays have more of an effect on the LGA traffic than on the JFK traffic. The landing operations for LGA and JFK would not have significantly changed if strict adherence of AFCP were observed. More aircraft would have have been ground delayed if strict AFCP's were practiced, (i.e., no exceptions).

The remainder of this section (excluding the summary) will be devoted to studying the AFCP parameters and resolving their influence in the system.

ERRORS IN LANDING RATE ESTIMATES

Landing rate predictions can be expected to be very sensitive parameters in the AFCP system. The predictions form the basis for the allocations which in turn set the arrival levels on the AFCP airport. Errors in these predictions will unbalance the planned demand capacity upon which the implementation of AFCP is predicated.

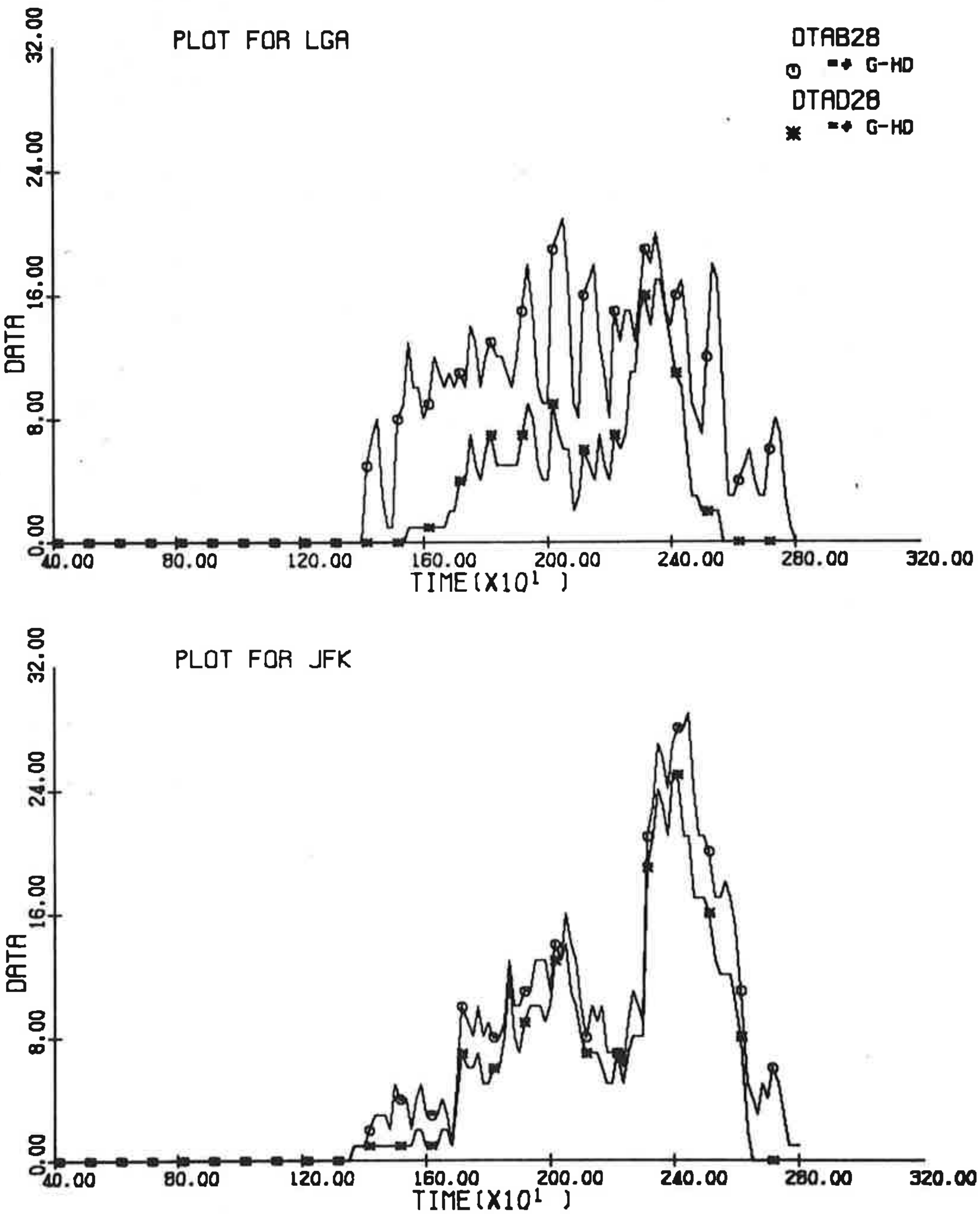

Figure 35. Comparison of AFCP Ground Delayed Aircraft and Weather Delays (Note: The difference between upper and lower curves on each graph shows the weather delay contribution)

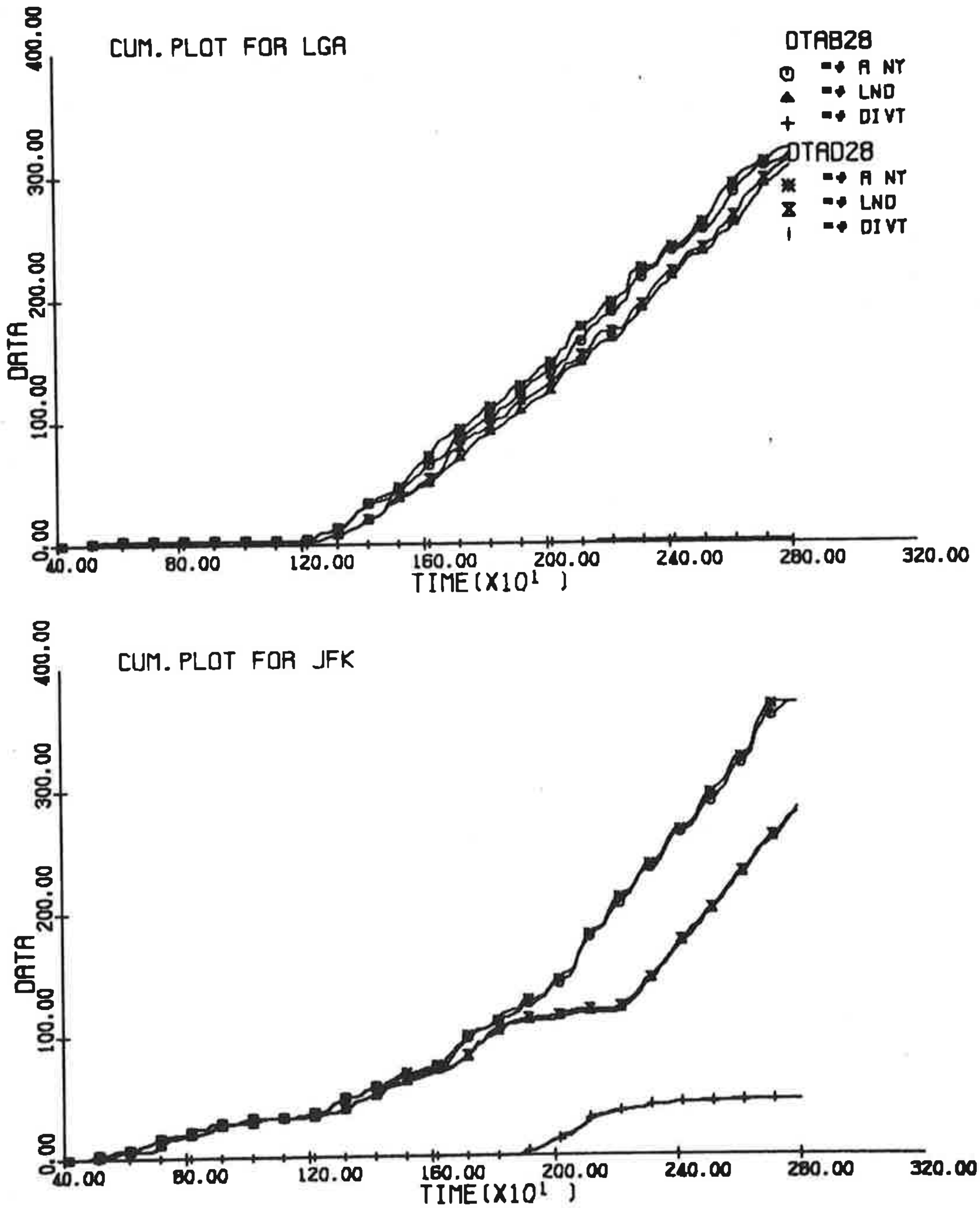

Figure 36. Weather Effects on LGA and JFK Traffic

Let us first look at the results of several simulation runs in which the only variation is in the landing capacities of LGA and JFK. All of these runs have AFCP in effect but do not have weather delays. Figure 37 presents the system comparison of run DTAD28, in which landings were simulated according to the actual landing capacities, and run DATY28, in which landing capacity followed the 8:00 a.m. AFCP predictions. It can be seen that for JFK, if the morning estimates had been perfectly accurate, there would have been no more than about 45 minutes air delay. Note that diversions would be almost nonexistent. Plotting the air holds* throughout the day for these two runs, (see Figure 38) it can be seen that sizeable stacks would not have materialized for either airport. A comment regarding the differences between LGA and JFK is warranted. The JFK landing capacity predictions were higher than those which developed, while the LGA predictions were on the average about the same. It was decided that an intermediate landing capacity halfway between the actuals and the predictions, would be helpful in studying the effects. Figures 39 and 40 present these results. The non-linearity of the effect of landing capacity errors can be seen in comparing Figures 38 and 40 for JFK. Although the rates are halfway between the extremes, the intermediate results (run DTAE28) are somewhat closer to the results of the estimated landing rates than the actuals. The non-linearity is such as to allow for reasonable errors in landing estimates but with larger errors the situation rapidly degrades. This is in agreement with the results of Figure 22.

Although the full investigation of better algorithms was not possible in the current study, some comments on improvements can be made. First of all, as pointed out in Section II, the current allocation algorithm does not provide for a continued one hour stack of holding aircraft. The stack of aircraft that exists at the time of AFCP initiation can fluctuate during the subsequent AFCP hours, because of bunching of arrivals at the beginning of the hours. In addition to the runs of Figures 37 to 40 several simulation runs where allocations were generated for the NAFEC data showed that stack fluctuation does occur. Therefore, any follow-up AFCP program should add the continuous stack feature to the allocation algorithm.

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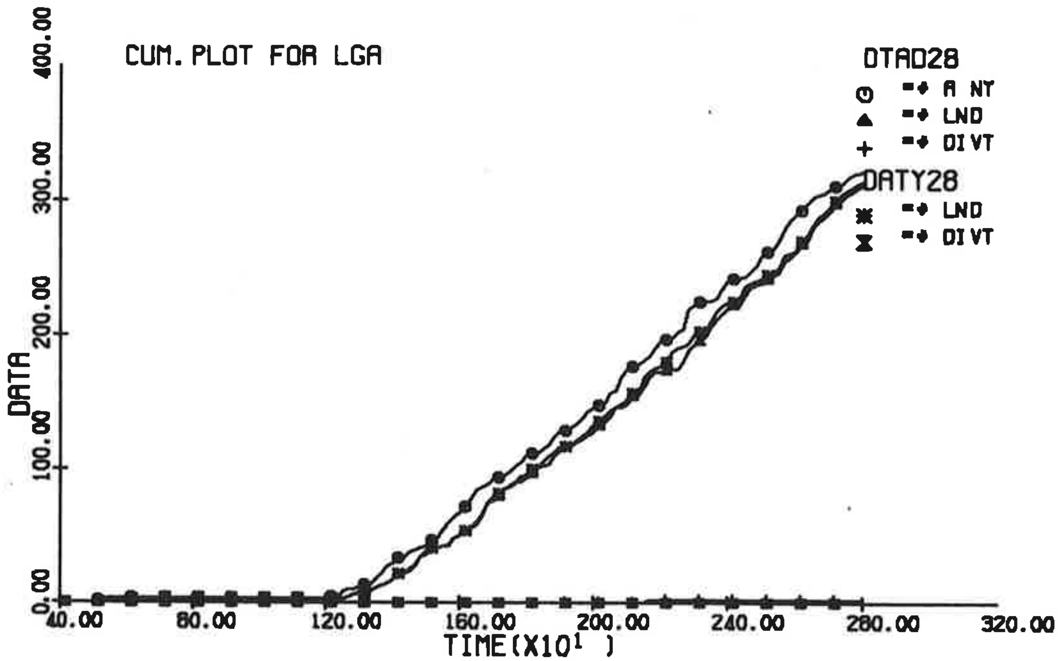
* Note that air holds are less than the difference between arrivals and landings, because arrivals are counted at the first New York fixes, which were usually 10 to 150 miles from landing.



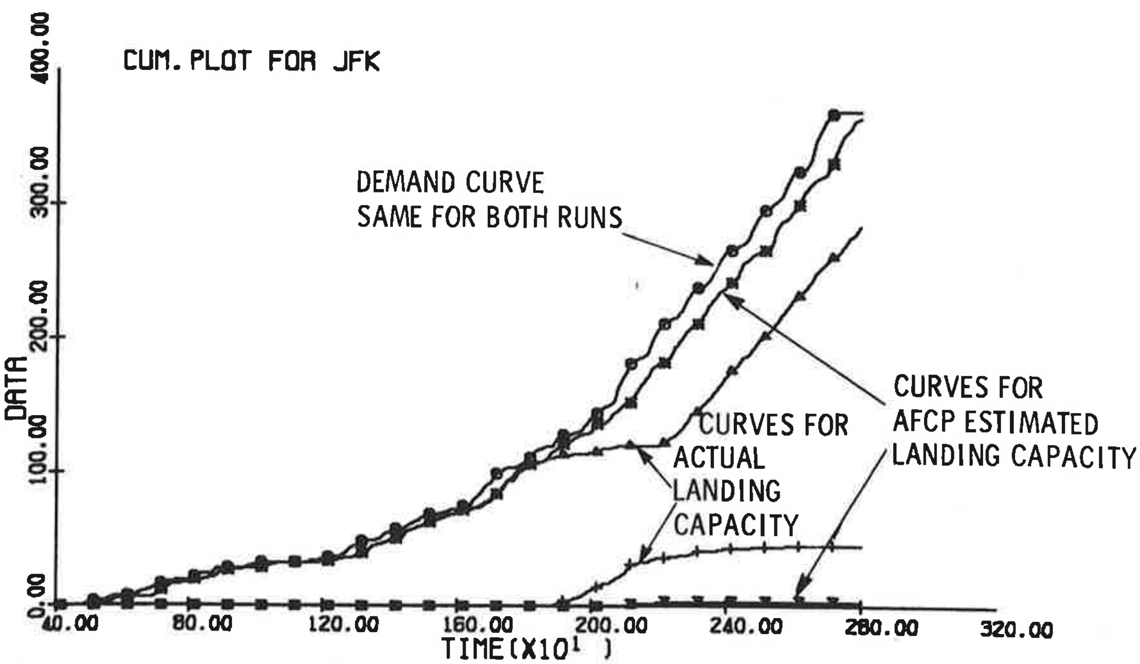


Figure 37. Cumulative Arrivals for Actual vs. Predicted Landing Rates.

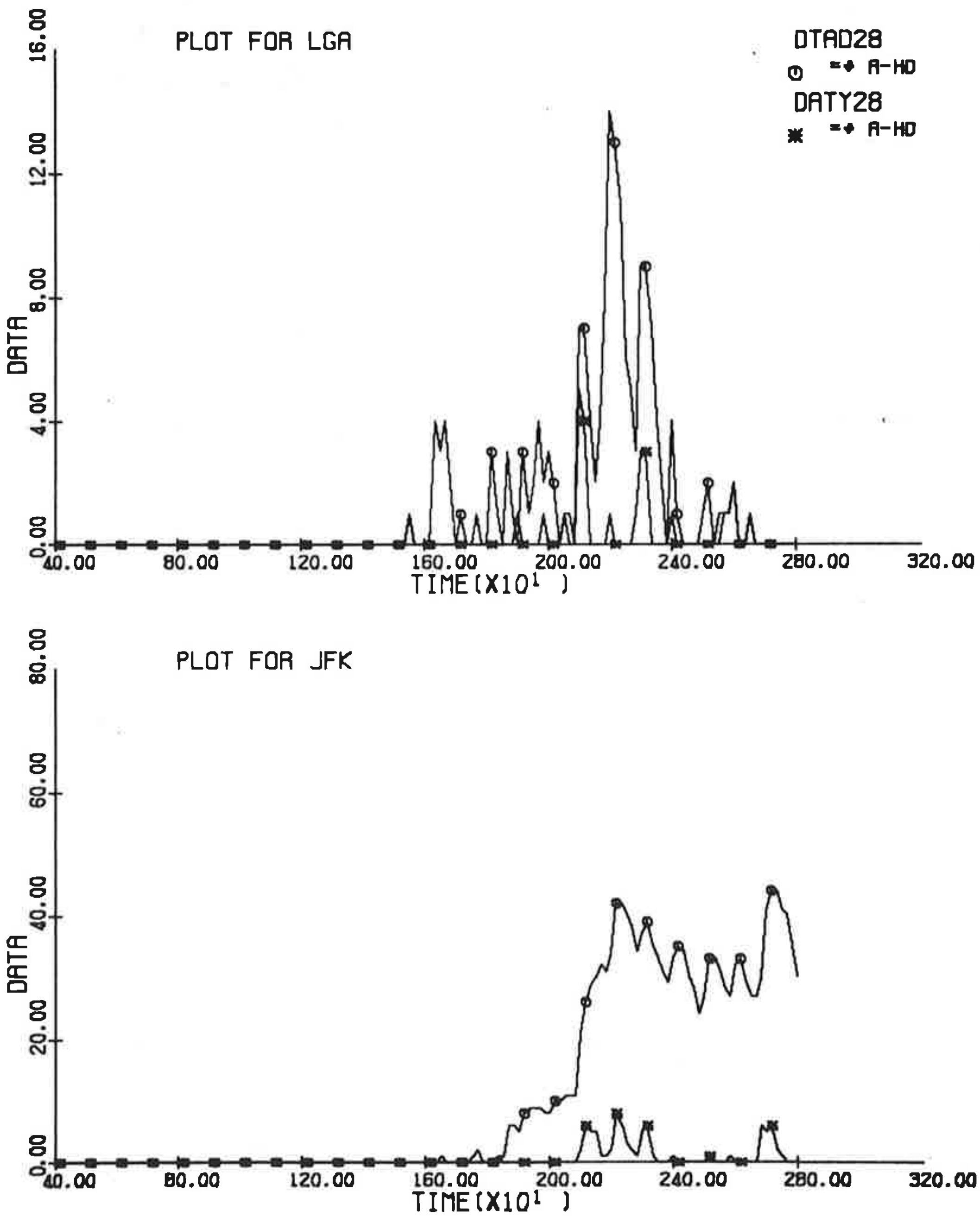


Figure 38. Air Holds for Actual vs. Predicted Landing Rates

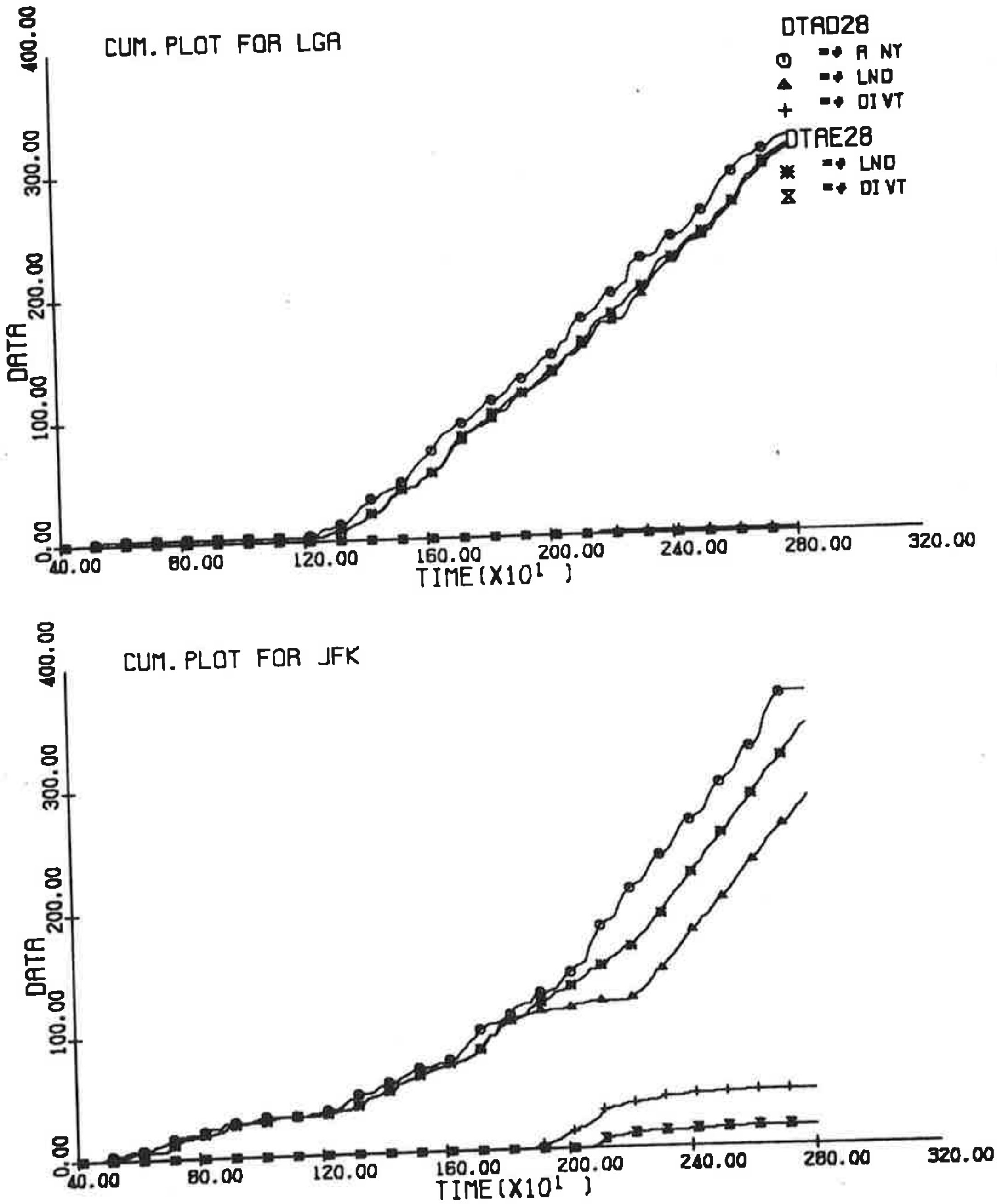


Figure 39. Cumulative Arrivals for Actual vs. Intermediate Landing Rates.

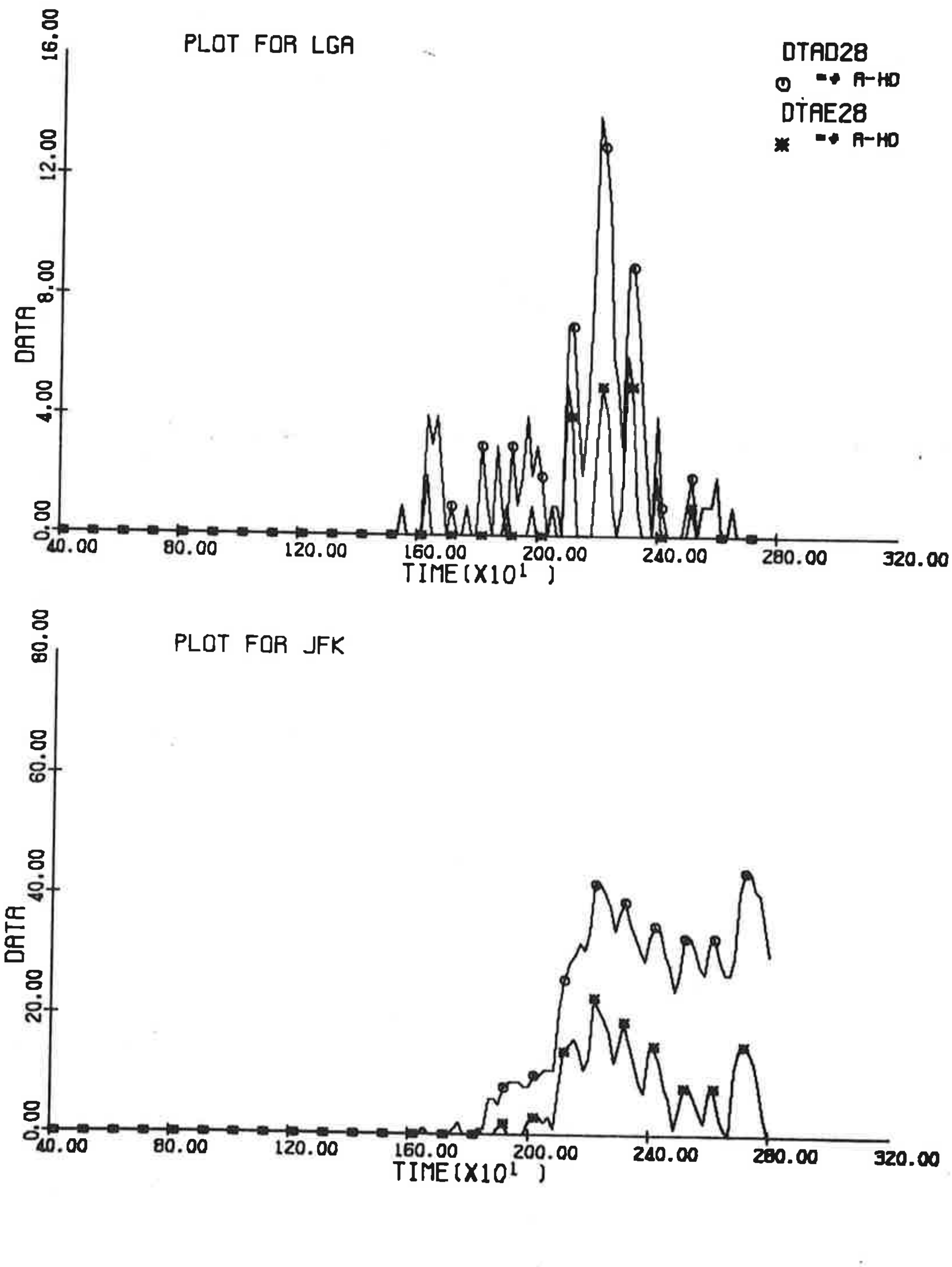


Figure 40. Air Holds for Actual vs. Intermediate Landing Rates

Secondly, the hourly interval for landing capacity estimates appears quite adequate. Several of the simulations used hourly capacities and several used 15 minute capacities. There were no significant differences between either capacity groupings.

Thirdly, the computer algorithm for allocations should allow for landing capacity prediction errors in accord with their variation from the normal landing capacity. Currently, a controller might apply this allowance by specifying the air delay (stack size) or by modifying the capacity estimates themselves. For example, if the best capacity prediction was 20 when the normal is 50 for a given hour, the input to the computer might be 25 if there was a concern for the holding stacks running dry. This is certainly a valid concern since an increase in the landing capacity over the prediction is more likely when the normal capacity is much higher than the prediction, i.e., there is more recovery potential. At the other extreme, when the airports are expected to be at their normal, full capacity but AFCP are implemented due to excessive demand, there is little need to allow for large errors in the estimated capacity. Thus the adjustment should be unilateral, i.e., applied only to estimates below normal. This kind of error allowance might be programmed into the algorithm where its application will be more consistent and mathematically more dependable. The controllers could then input their most accurate estimates of capacity, plus a specified air delay or stack size, with knowledge that the computer will generate the allocations with proper allowance for prediction errors in the given situation.

EFFECTS OF REVISING THE ALLOCATIONS

As discussed in the previous section entitled FEBRUARY 5, 1971 CASE STUDY, as the day progressed the allocations were revised upward in response to ARTCC requests for more slots and possibly because of the New York ARTCC's re-evaluation of the capacity. The simulation showed that, had the allocations been adhered to rigidly, the revisions would have had a noticeable effect on the system's traffic flow, as seen in Figure 41, and on the holding stacks, as seen in Figure 42. In these figures run DTAC28 shows the results for the original allocations and run DTAB28 presents the results for the revised allocations.

Looking at the JFK situation, the arrivals were increased over the period from 2100Z to 0300A as a result of the revisions. During this same period the average number of aircraft holding over New York was increased from 20 to 30 with typical air delays going from 60 minutes to 80 minutes. The LGA holding stacks were not appreciably changed. This is partly because of the lower net

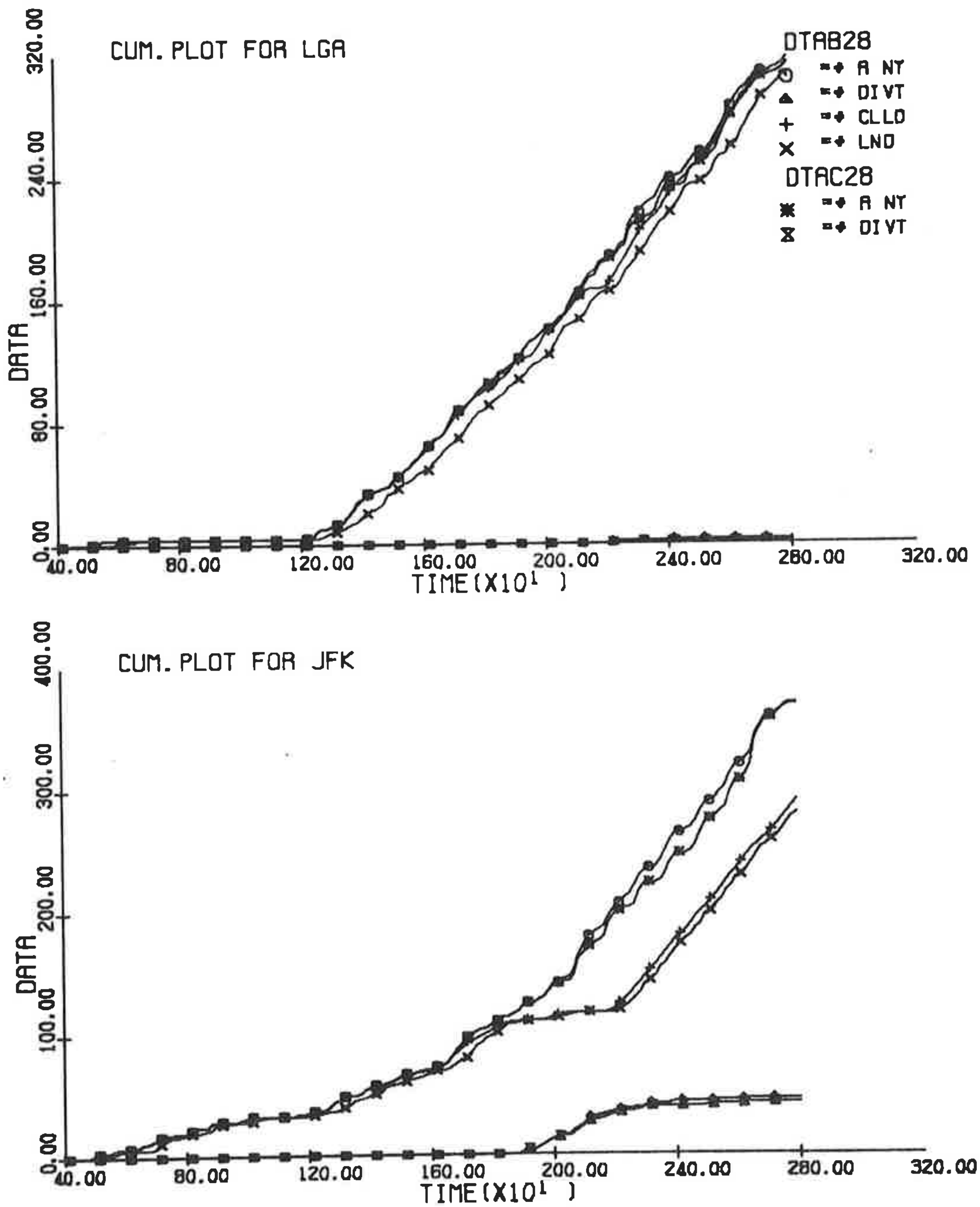


Figure 41. Cumulative Arrivals for Revised Allocations

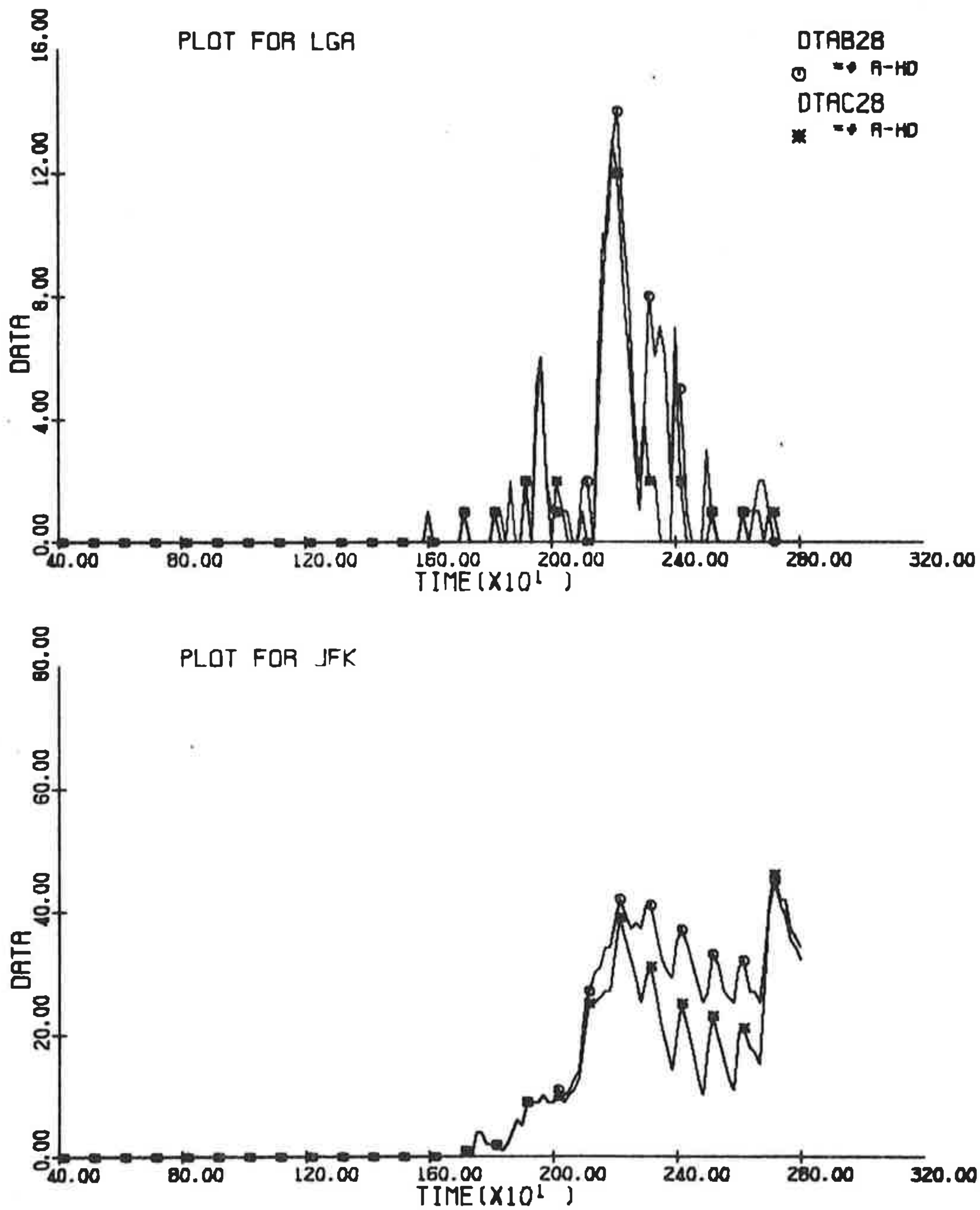


Figure 42. Air Holds for Revised Allocation

changes to the LGA allocations (up 28) than to the JFK allocations (up 46). There is, however, a proportionate change in the number of aircraft delayed on the ground by AFCP. Figure 43 shows the cumulative count of ground delayed aircraft destined for LGA for both simulation runs. The large change in ground delays for LGA in Figure 43 contrasts with the apparent small changes in air holds and landings shown in Figures 41 and 42. This is due primarily to the adequacy of the LGA landing capacity for both demand loads (with associated small air delays). The JFK demand/ landing capacity unbalance, on the other hand, caused the air delays to change proportionately when demand changed. From this limited example, it appears that the AFCP system is not as sensitive to demand changes when the actual landing capacities are close to arrival demand as when they are below demand. Therefore, when capacity drops during the AFCP period, it is very desirable to revise the allocations and thereby revise the arrival demand. This revision is, in essence, a feedback of system status, overriding original controls. An important consideration in an improved AFCP system should be the provision for this feedback of status and updating of controls (allocations) when the original predictions become increasingly inaccurate as the day progresses.

An alternative to revising the allocations is to delay implementation of AFCP until the latest practical time to make the landing predictions more accurate. If Zone 3 (West Coast) for JFK were eliminated from AFCP, for example, the time of notification before AFCP implementation could be reduced to five hours. The AFCP computer program, however, would have to compensate for this Zone 3 traffic in the quotas allocated to the other zones, as discussed on page 81, Cases 7-10.

Before leaving this discussion of allocations, it is very apparent that a wave effect is present in the simulations of strict AFCP operations, (see Figure 42 and the #A New York curves on Figure 41). What is happening is that AFCP ground-delayed aircraft are given an ATA (assigned time of arrival) 15 minutes into the arrival hour. For example, flight X was originally scheduled to land at 0210Z, but due to the allocation restriction he must be delayed into the 0300Z hour. The first 15 minute rule is applied, which results in an assigned arrival time (ATA) of 0315 and his ATD set at the ATA minus his ETE. With large numbers of AFCP ground delays, one therefore would expect waves of aircraft to enter the New York ARTCC so as to land at 15 minutes past the hour. This is not the most desirable traffic pattern. Some of the wave is spread by variations in enroute times, gate departure delays, etc., but as will be shown below, these smoothing factors are not adequate (when AFCP is accurately observed) to distribute the traffic uniformly through the arrival hour. However, among other possible solutions the 15 minute rule may be modified to smooth the flow by giving each ARTCC a specified minute rule, differing for each ARTCC.

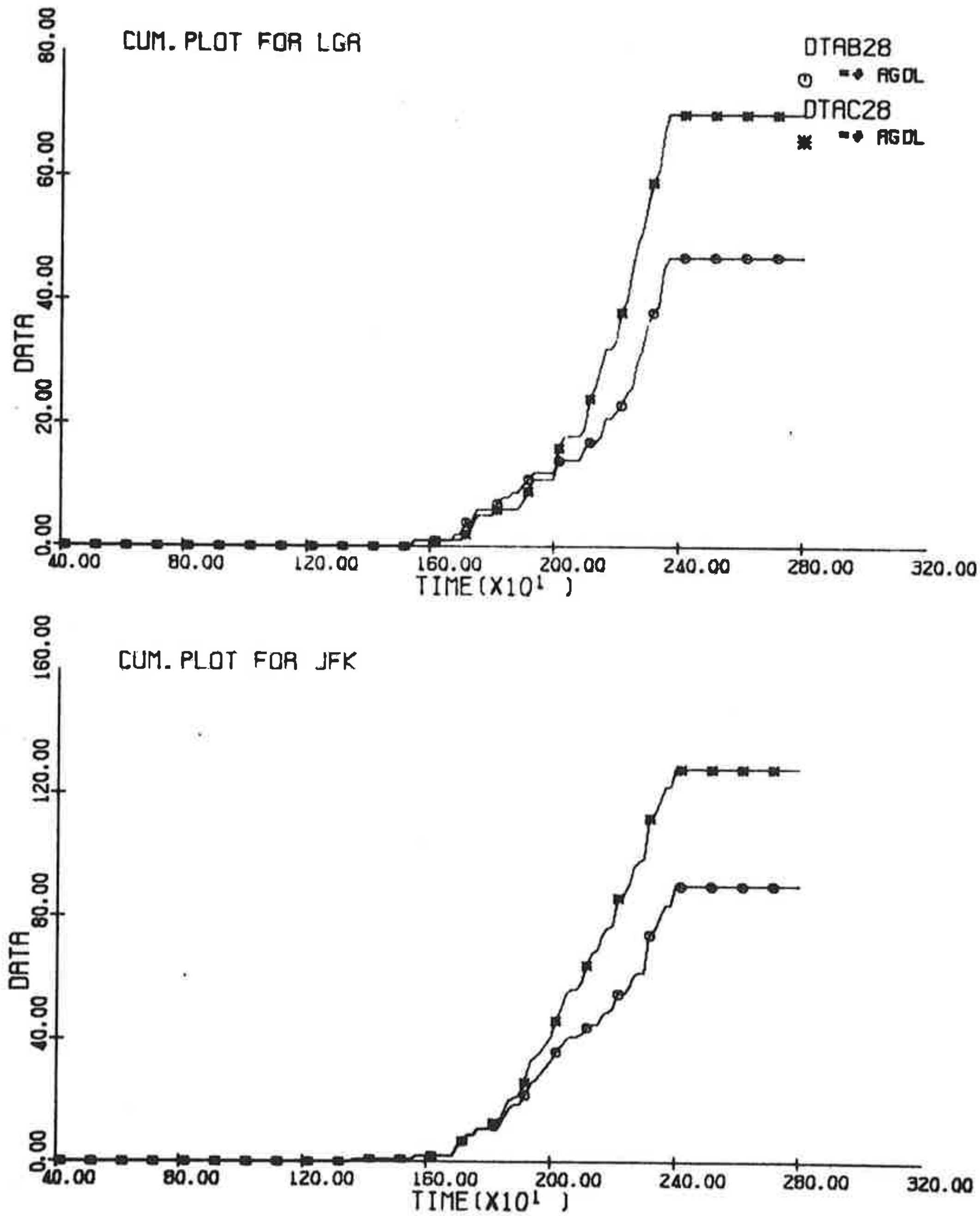


Figure 43. AFCP Ground Holds for Revised Allocations

EFFECT OF 15 MINUTE RULE

As discussed earlier the 15 minute rule is intended to allow for late arrivals from the previous hour and to prevent flights that depart prematurely from arriving during the preceding hour (7230.9A allows ± 15 minute variations from ATD's). From the discussion of the wave effect presented previously in this report, one would expect that this rule would merely translate the steps of Figure 1 to the right by 15 minutes. Thus the 45 to 105 minute extremes in the air delays of that example would become 30 and 90 minutes, respectively. The simulation verified that such a shift does occur, as follows:

Figure 44 presents the results of two simulation runs, one with the 15 minute rule (DATI28) and the other without it, (DATJ28). The arrival curves (#A NY) do indeed exhibit the expected steps, with a slight relative displacement. In order to verify that the displacement is due to the 15 minute rule, an exaggerated rule was simulated. Figure 45 gives the comparison of the 15 minute rule with the simulation results of a 45 minute rule (DATK28). One can see that when the rule is strictly enforced as it is in the simulation, the net effect is to shift the demand by the number of minutes used in the rule, in effect reducing the air delays.

Since air delays can be controlled more directly by the allocations themselves, as discussed in the recommendations and in the section entitled ANALYSIS OF AFCP, it would seem that the 15 minute rule is unnecessary. This does not mean that some modification of the rule may not be useful. One possible modification was mentioned in the previous section, that of distributing traffic by assigning different arrival times within that hour to different ARTCC's. For example, the allocations for one group of the ARTCC's could start at 20 minutes past the hour instead of on the hour. The result would be that the centers' AFCP ground delayed aircraft would be cleared for arrival at 20 past the hour. Other centers would be given allocations for 20 minutes before the hour, and others for on the hour. This technique would produce three waves of traffic instead of one. The three waves would be considerably smaller and possibly indistinguishable from uniformly distributed arrivals.

ENROUTE TIME VARIATION EFFECTS

The question concerning enroute delays and early arrivals was investigated to see what effect these time variations would have on arrivals. Two identical simulations were run, the only difference being a ±10% uniform variation in each aircraft's cruise speed in one of the runs. This in effect produced random arrival times at the first fixes in the New York ARTCC. For

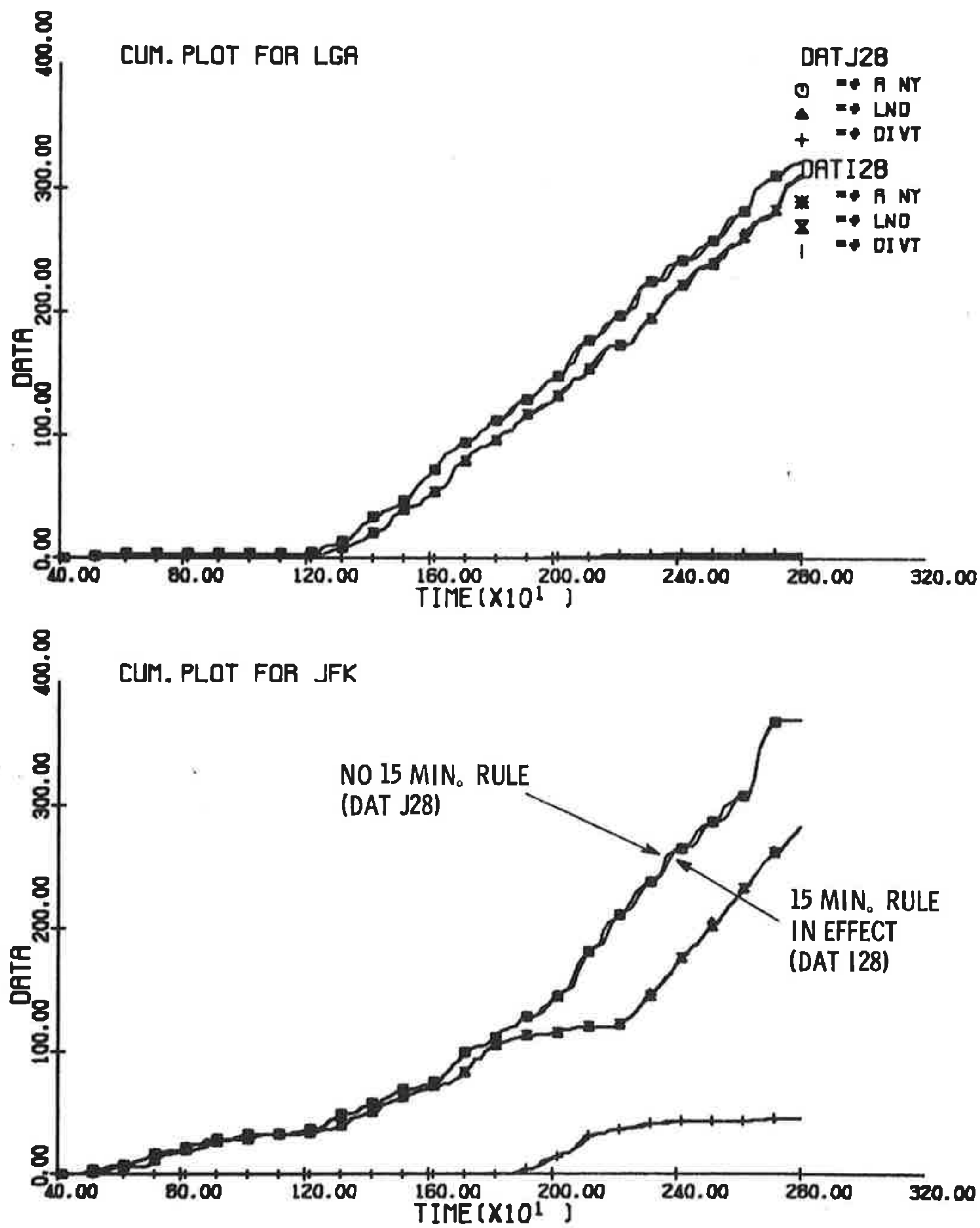


Figure 44. Cumulative Arrivals with the 15 Minute Rule

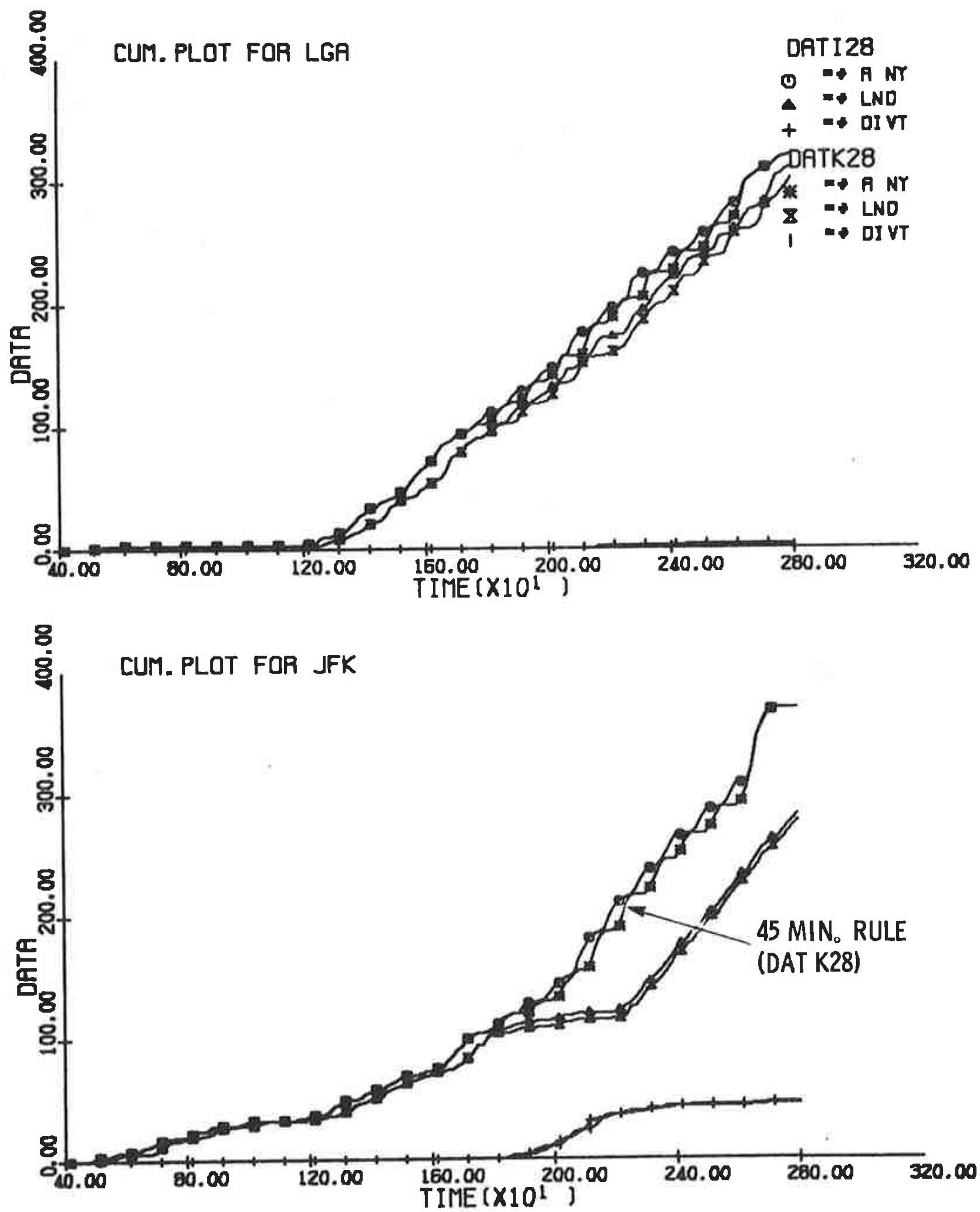


Figure 45. Cumulative Arrivals for 45 Minute Rule

example, if an aircraft had a two hour cruise phase prior to his arrival at the New York ARTCC, the simulation would fly him to the first fix in anywhere from 1 hour and 47 minutes to 2 hours and 13 minutes depending on the result of a random selection of a number from -13 to +13. The results of these two runs are shown in Figure 46. The difference in the demand (#A NY) is negligible. A more sensitive indication of the differences might be expected in the air holds (see Figure 47). Again, no worthwhile effect. It is therefore concluded that under heavy traffic conditions the individual aircraft enroute delays and early arrivals (result of tail winds for example) have little effect on AFCP operations.

EFFECTS OF EARLY AFCP CANCELLATION

The last major factor discussed in this chapter is that of AFCP cancellation prior to the original announced closing time.

A simulation based on the February 5 data was conducted in which AFCP was allowed to run to completion at 2700 as originally scheduled (DATI28). Comparison with a similar run where AFCP was cancelled three hours early (DTAD28), produced the expected results. Specifically, the demand level (arrivals in the New York ARTCC) rose shortly after the time of cancellation above the level held during the full AFCP period. Of more interest than a plot of arrivals is Figure 48 which compares the difference in air holds. Run DATI28 shows that the holding stacks for JFK would have dropped to less than 12 aircraft while there was a leveling off around 30 aircraft stacked with the early cancellation of AFCP. One can still see the wave effects after the cancellation because the pattern was established by aircraft with ETE's in excess of one hour (i.e., the aircraft were enroute in waves at the time of early cancellation notice). It will also be noted that a sharp rise in the holding stack at JFK occurs when AFCP is cancelled at the originally planned time of 2700. (This rise did not occur on February 5 because the allocations were not realized in practice.) The rise is due to a demand increase and appears also on the early cancellation run.

The interpretation of these runs is that premature cancellation of the allocations can cause an increase in the number holding. In contrast, the delays will eventually diminish to zero if the AFCP allocations are calculated correctly and continued indefinitely. Hence it appears that the only danger is premature cancellation and that the safe course in a successful AFCP operation is to allow the delays to dissipate before removing the procedures.

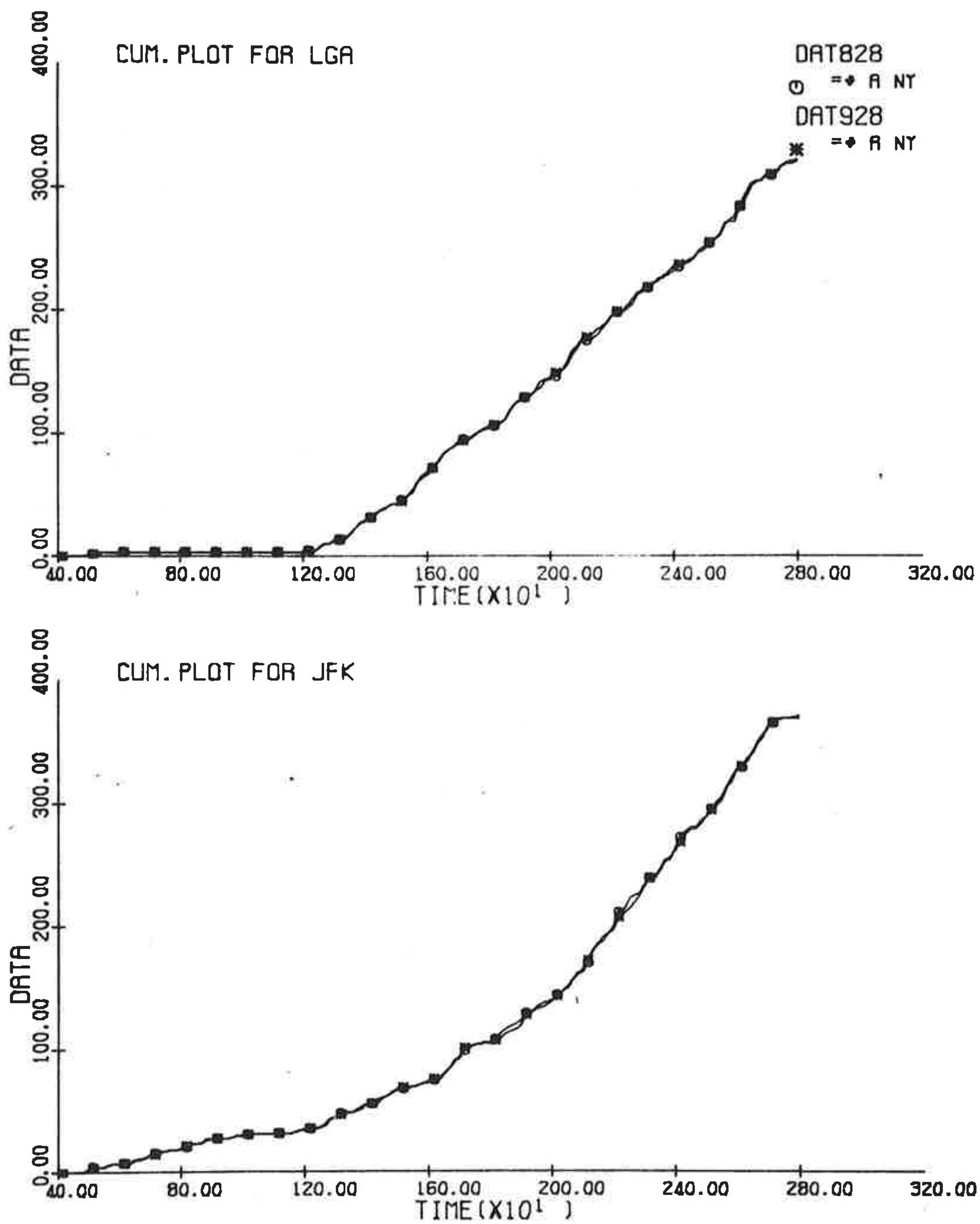


Figure 46. Effect of Enroute Time Variations on New York Arrivals.

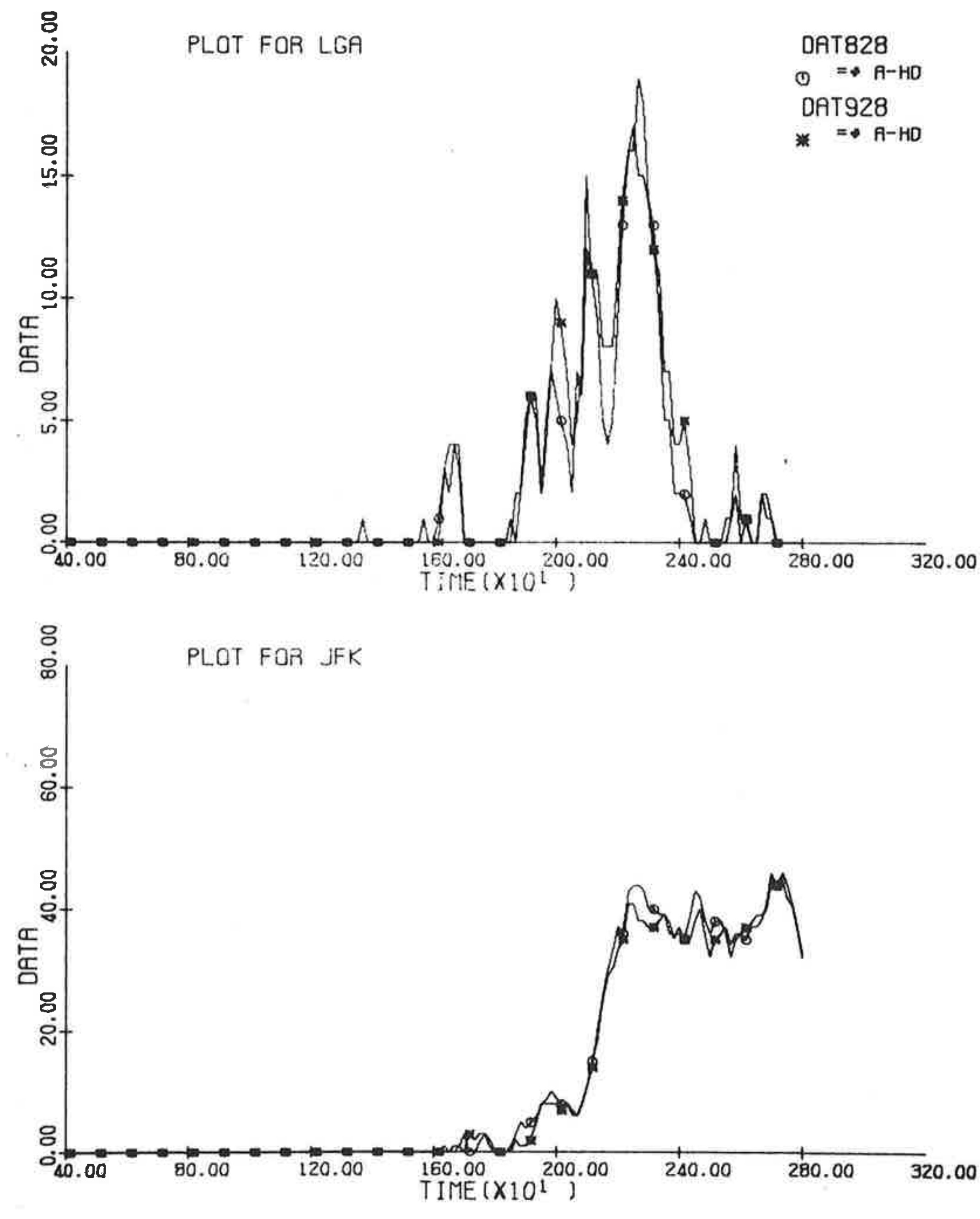


Figure 47. Effect of Enroute Time Variations on New York Air Holds

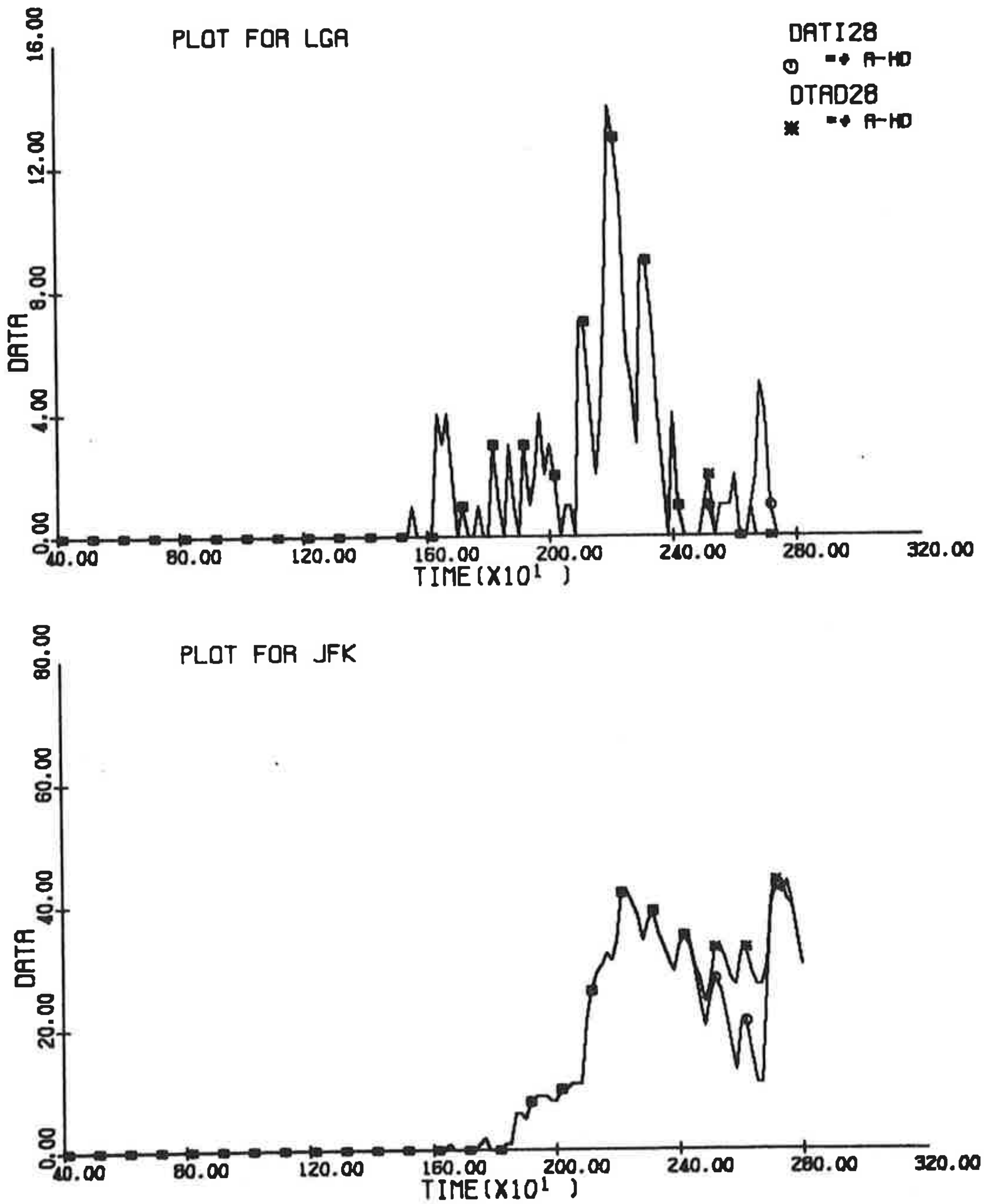


Figure 48. Effect of Early AFCP Cancellation on Air Holds

SUMMARY OF SIMULATION RESULTS

The VAST simulation program was modified to replicate the traffic flowing into JFK and LGA on February 5. A series of runs showed that the simulation agreed with the actual traffic, both statistically and for individual aircraft, well enough to exhibit qualitative effects and to make valid comparisons. The results of applying the simulator are summarized as follows:

1. Strict application of the modified allocations on February 5 would have reduced the arrival demand on JFK. This verifies the results of the section entitled FEBRUARY 5, 1971 CASE STUDY, that although the total modified allocations were above the demand level, their application on a center-by-center basis would have resulted in fewer arrivals than actually occurred. The simulation also indicated that somewhat reduced air delays and diversions and increased ground holds would also have occurred.
2. Weather in the "Golden Triangle" would have affected LGA arrivals more than JFK arrivals, because a greater percentage of LGA flights would experience departure delays.
3. The simulation verified that air delays are non-linearly related to landing capacity estimation errors, as shown in the section entitled FEBRUARY 5, 1971 CASE STUDY. Large errors have a disproportionately large effect on air delays.
4. Air delays are more sensitive to capacity changes when capacity is below arrival demand than when they are about balanced. If estimated capacity, allocations, and arrivals all agree (as they should under AFCP), this means that air delays are more sensitive to capacity estimation errors when the capacity has been largely over estimated than when the estimate is about correct, or low.
5. Several simulation runs showed that waves of arrivals, i.e., steps in the cumulative arrival curve, would occur if allocations were applied by the centers at the beginning of each arrival hour. This coincides with the results given under ANALYSIS OF AFCP.
6. The major effect of the "15 minute rule" is to translate the arrival curve steps to later time.
7. Enroute speed variations of $\pm 10\%$ have little effect on the arrival curves.
8. Early cancellation of AFCP allocations can cause an increase of air delays.

These simulation results have several implications:

1. They show that applying and modifying the center allocations can have a major bearing on the results of AFCP. Although the allocations made for JFK on February 5 were well above the actual capacity and also above the demand, nevertheless, they would have had beneficial effects if strictly applied. This suggests that improved application techniques should be investigated.
2. The simulation results suggest that some means of taking account of departure delays, particularly those due to weather, should be employed in the procedures, especially for traffic to LGA.
3. The simulation results (3) and (4) above point up the need for accurate capacity estimated and prompt revision of allocations based on those estimates.
4. The simulation of arrival curves with steps (arrival waves), even with the 15 minute rule in effect, indicates that some means of controlling the arrival rate to a more uniform value should be employed. Since the 15 minute rule merely advances or delays the steps, it may be replaced by a modified rule that produces several smaller steps rather than one large one.
5. It appears that the procedures should prevent early cancellation of AFCP restrictions, allowing them to continue at least until changes in demand and capacity have brought air delays to zero.

FINDINGS AND RECOMMENDATIONS

SUMMARY OF FINDINGS

The FAA Orders were examined in order to identify and to quantify the objectives of the AFCP, with the following results.

The intent of AFCP was clearly to shift air delays at the destination terminal to ground delays at the points of origin, but to do so in a controlled manner so as to prevent loss of landing capacity on the one hand, and excessive air delays on the other. (1)* The control of air delays serves to avoid unsafe accumulations of aircraft in New York Center and backups into adjacent centers, to reduce diversions, to avoid inequities in service, and to provide arrival delay predictions. (1) Given these intents, the effectiveness of AFCP can be measured most conveniently by the total of aircraft hours lost in the air at the destination terminal, plus aircraft hours of lost landing capacity, augmented by delay distribution plots. (2)

The manual and computerized procedures were examined (3, 4) to determine how, and to what extent, they carried out the intent of AFCP.

The manual procedures were based on historical demand data, capacity estimates made up to eight hours before arrivals, and hourly allocations. The center allocations were devised by New York ARTCC on the basis of demand, estimated capacity, and judgment (3); they were applied within the hour by the receiving center, subject only to the first 15 minute rule and the sequencing rules called out in the orders. (5, 6)

The main improvement made possible by the computer program was a detailed and up-to-date demand list and more accurate allocations. The improved delay prediction and control possible with this information, however, is compromised by the following several circumstances, some inherent in the computer program, some inherent in its use.

1. AFCP is initiated at the beginning of an hour, at which time the air delay is usually not equal to the desired air delay at New York, but somewhere between it and zero. (7)

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* The numbers in parentheses are references to the preceding sections of this report. A cross reference is included at the end of this section.

2. The allocations issued are for an entire hour, and expeditious release of aircraft by the field centers would produce waves of arrivals at New York Center, adding additional 60 minute peaks to the air delay obtained at the start of AFCP. (7)
3. The allocations for centers are drawn from the TATA (Tentative Assigned Time of Arrival) list, starting at AFCP initiation time, without allowance for flights arriving prior to AFCP initiation. This produces erroneous center allocations, although the total allocations are correct. (7)
4. The timely initiation of AFCP by the New York flow controller is hindered by the fear of lost capacity (justified, in part, by 1. above) and by lack of familiarity with the computer program. (8)

The February 5th Case study brought out some of the major difficulties in carrying out the AFCP, even though the KC computer was inoperative on that day. Because of poor weather over the eastern United States, much of the traffic scheduled for New York was cancelled. (9) This cancellation information would have been essential for a successful AFCP operation on February 5th. (10) Secondly, the estimated capacities at LGA were only slightly less than the average actual capacities which fluctuated over a large range, (11); at JFK the actual capacity was far below the estimated at the start of the AFCP period, due to low visibility, but came into agreement abruptly four hours later. (11) Finally, extensive exceptions to the allocations were requested by, and granted to, the centers, but the coordination required to keep these in agreement with estimated capacity was apparently lacking. (12)

By using the February 5 data, it was possible to determine what would have occurred under certain conditions. If the JFK capacity had been estimated at, or revised to, the range 10 to 20/hour, a 2:1 improvement in effectiveness would have resulted; (13) a slight improvement could have been achieved at LGA by a capacity estimate of 25/hour instead of 20. (13) If capacity were known ahead of time, and flights individually dispatched, then reducing the assigned air delay at New York from 60 minutes to 0 minutes would have improved the effectiveness of AFCP. (13) In addition, reducing the notification time to four hours, using a simple prediction scheme, and revising the capacity estimates and allocations each hour, would have reduced the total of air delays and lost capacity to less than half of what actually occurred at JFK. (14)

The VAST simulation program verified and augmented the above results. It showed that the arrival waves expected from the procedures would occur in a general situation, (15) and would have been observed in the February 5 data along with a reduction in arrival demand had the allocations been achieved on a center-by-center basis. (16, 17) The simulation also showed that the first 15 minute rule would produce minor differences in the New York arrivals, (18) and that randomly varying the enroute air speed by ±10% would have had negligible effect as well. (19) It also showed the large effect of national weather patterns on the New York arrivals, (20) particularly LGA, (21) and that the air holds and diversions are non-linearly sensitive to errors in landing capacity prediction. (22) Finally, it showed that premature cancellation of AFCP will increase air delays, (23) and that continual revision of the allocations is desirable. (24)

INTERPRETATION OF FINDINGS

The success of the AFCP hinges on the control of air delays at the destination airports. From this control most of the subsidiary objectives follow. But at present there are several impediments to achieving such control:

1. The present implementation does not, even in principle, provide a positive, predictable control of air delays.
2. The application and revision of the allocations, if not carried out properly, can completely void any calculated control of arrivals.
3. There is no set procedure to revise landing capacity estimates, which have a strong influence on the air delays.
4. Extensive cancellations, such as occurred in the case study of February 5, can make demand prediction ineffective if they are not recorded through ARO or if the computer is not functioning, as on February 5.
5. The effects of national weather conditions on cancellations, take-offs, and airport landing capacity are pronounced and are only indirectly allowed for in the present implementation.
6. Effects such as premature cancellation, the first-15-minute rule, and possible inequities in delays reduce effective control.

AFCP were almost completely ineffective on February 5 because of these impediments, in addition to the computer malfunction. But the data gathered provided a traffic/capacity sample from which an encouraging conclusion can be drawn: <u>There are no impediments to effective ground control that cannot be removed or greatly alleviated by changes in procedure or in the computer program</u>. None of the six difficulties listed presents an unavoidable limitation to AFCP. The unavoidable limitations to controlling arrivals are: landing capacity prediction accuracy, uncontrollable departure delays, and enroute time variations.

Consider the landing capacity estimation problem. The study showed that reducing the notification time and revising the estimates each hour would have doubled the effectiveness, even though capacity prediction was no more than simple projections of observations. This prediction scheme can be improved by allowing for runway configurations, weather, etc. The results should be at least as good as obtained in this study for JFK using the February 5 data, which represent a case of extreme capacity variations.

The problem of departure delays (other than AFCP holds) presents a fundamental restriction only in so far as they are unknown and unpredictable. Although takeoff delays may be estimated by the centers concerned, and input to the computer program, some residual error must be expected. The calculations discussed above in connection with landing capacity used the same takeoff delays as actually occurred for 60% of the flights (those not given AFCP delays), and no uncontrolled departure delays for those under AFCP, (13,14). The improved effectiveness that resulted indicates that unpredicted ground delays will only partially impede the effectiveness of AFCP.

Finally, the problem of enroute time variations must be considered as an unavoidable limitation on AFCP. But the simulation showed [19] that normal enroute speed variations have little effect on New York arrivals. Moreover, this was borne out by the February 5 data, [26] in which enroute delays were a small fraction of the total delays.

The interpretation of the findings, then, is that there are no difficulties in controlling arrivals that cannot be removed or alleviated. The causes of ineffectiveness on February 5 all fall into that category, and, in general, the six impediments listed can all be removed or reduced.

RECOMMENDATIONS

I Retain AFCP

The preceding discussion has concluded that changes in procedures and in the computer program can make the AFCP work effectively. The recommended changes will be discussed below. The question addressed here is whether AFCP should be retained at all, assuming such changes can be made. The answer depends on whether the objective of AFCP is worthwhile, and whether a (modified) computer program is the best way to achieve those objectives.

The objective of the AFCP is to control arrival air delays by shifting them to ground holds. Under the high demand conditions of 1968, such a shift may have been required often, but under the lower demand conditions of 1971, the necessity has been questioned. But arrival delays are the results of a high demand-capacity difference, and that can occur under relatively low demand conditions if capacity is reduced by poor weather, equipment outages, etc. In fact, this is just what occurred in the case study. Since no general improvement in the weather, and only a gradual improvement in low visibility landing rates can be expected, it follows that some control of air delay will be required occasionally even in the absence of high demand.*

Is modification of the present AFCP program the most efficient way to achieve the desired objectives? In particular, is a computer program required at all? It seems clear that computer based demand information, especially cancellation data, [27, 28] is required for effective AFCP operation. The poor effectiveness of AFCP on February 5, for example, was largely due to the unavailability of accurate demand and cancellation information. Although the center allocations can be calculated approximately by hand from capacity estimates and traffic experience, [29] their accurate breakdown by hour requires extensive demand data and manipulation. [30] The study showed such a breakdown is very desirable [30, 31] Further, if hourly revisions are to be made [15,32] and the delay at initiation calculated, [30] as recommended, the burden would be excessive for manual operation.

In addition to the above, there are other reasons for retaining the AFCP. These procedures are the only means at present to anticipate terminal delays and control them at an inter-center

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* The net value of the AFCP, however, can be measured properly only in a cost-effectiveness study, which was not undertaken in the present project. An approximation of the value of the procedures can be obtained from the February 5 case study, however. The total air delay for the two airports was 784 aircraft hours; an effective AFCP operation could have changed it to 292 aircraft hours, (Case 8, Table IX). Using an approximate figure of $5.00/ minimum for the difference between air and ground operations gives a saving of about $15,000. This would have to be reduced to allow for an increase of 43 hours in lost capacity that would have occurred, plus the cost of running the AFCP program. This running cost depends on the computer employed and on whether it is time-shared or dedicated, and on the modifications made to the program, if any. These costs were not investigated in the present study, but a conservative guess at the net savings for the February 5 case is $10,000.

level. Their use will provide valuable data for flow control, since it is inevitable that an effective national flow control system be based on ground holds as well as air holds and reroutes.

Finally, it should be pointed out that the accurate prediction of air delay is valuable in itself, as well as being needed for control. In fact, delay predictions may be issued even though the procedures are not implemented. Routine use of the program to predict arrival delays has many advantages: it is a more cost-effective use of the software development expense, it provides useful information to the users and to the field centers, it allows gathering data to improve the program and for flow control in general, and it creates and maintains familiarity with the program on the part of the AT personnel.

II Modify the Procedures

<u>Assign Responsibility for Initiating and Implementing AFCP to the Central Flow Control Facility</u>

This change will eliminate some of the difficulties found in the present operation by putting it on a national, rather than on a center basis. Central Flow Control has a better overview of the national traffic that is affected whenever AFCP are implemented and is thus in a better position to make the initiation decision. Moreover, the implementation of AFCP affects traffic in all centers; since $(CF)^2$ is responsible for coordinating traffic between two or more centers, it is presently responsible in theory for making AFCP work effectively. Therefore, it should control their implementation. It should remain the perogative of the destination center to specify their acceptance rates, but $(CF)^2$ should have the responsibility of issuing and coordinating allocations and/or restrictions to achieve those rates. The specific reasons for this recommendation are as follows.

The first reason is the national, or inter-center, nature of the AFCP, which is clear from the preceding findings. At least three of the stated impediments to effective air delay control have to do with national, as opposed to local, problems. These are effective application and revision of the allocations; maintaining and updating demand data (particularly cancellations); and allowing for the effect of national weather patterns on demand.

1. <u>Allocations</u> - The study has shown that application and revision of the allocations, if not carried out properly, can void effective control.[31, 32] While the present system of swapping via coordination centers accomplishes

this in theory, it does not always do so in practice, as seen in the case study.[31, 33] A central coordination point, working through the coordination centers but removed from the immediate workload of the field centers, can best apply and revise the allocations. There is little reason for the center of the receiving airport to carry out coordination between other centers.

2. Demand Data - The proximity of the CFCF to ARO can improve the accuracy of demand information used in the AFCP. If the program is used routinely to predict delays, then a continual check on demand data can be made, and inaccuracies rapidly corrected. Also, the reliability of the data communication will be improved by the physical proximity of ARO and CFCF. The extensive cancellations of February 5 were probably not known to New York Center because of the KC computer failure and because of the lack of any automatic communications other than through the KC computer. They may, possibly, have been transmitted from the ARO via telephone to New York but a more reliable transmission would have been achieved from ARO to CFCF.
3. National Weather - The importance of this information was brought out in the simulations.[33] Not only is CFCF the natural focal point for national weather information relative to air traffic, but it is also in the best position to solicit and obtain timely information on the consequent departure delays. Such data can then be input to the computer program by CFCF. Also, in carrying out its planned functions CFCF will eventually have to project the effects of weather movements on capacity; doing so for the AFCP will provide a start on this capability.

Second, if, as seems desirable, AFCP is extended to other major hubs, (see below), then it is advisable to have central coordination because of potential interaction between terminals under AFCP, and the extensive coordination required among them.

Third, is the fact that ground holds must become one of the working tools of flow control, along with air holds and reroutes. Exercising an existing ground hold program such as the present KC program is an excellent start towards an automated systems flow control capability.

The fourth consideration is that of obtaining more objective New York landing capacity estimates. It appears to TSC, based on discussion with the ZNY staff, that the establishment of acceptance rate estimates in New York center is, at present, unavoidably confounded by the anticipated consequences of those estimates.

It is more difficult to make an objective estimate of landing capacity if that estimate is, in effect, the decision to initiate AFCP. Although this is a purely psychological difficulty, which may be overcome by further training and experience with AFCP, it is nevertheless real and likely to remain as long as the AFCP are employed only rarely and as an extraordinary measure. Therefore, it is recommended that (a) the responsibility for capacity estimates be retained by the ARTCC flow controller, but (b) the demand and delay calculation be carried out by computer at CFCF, (c) the decision to initiate AFCP be taken when the calculated delay reaches a predetermined level (as at present), and ratified or rejected by CFCF after consultation with the ARTCC flow controller, and (d) the capacity estimates and delay calculations both be made on a regular basis. This arrangement will assign logically distance functions to different groups, provide a well defined interface (i.e., the capacity numbers), and allow AFCP initiation to arise out of a routine process.

A fifth reason is that $(CF)^2$ is in an excellent position to gather data on AFCP operations, because of its contact with the centers, the airlines, and the various weather services. Recommendations for data to be logged will be made below.

<u>Eliminate Zone III and Denver from AFCP Allocations; Reduce Zone II Notification Time to Four Hours</u>

This change should apply only to capacity-actuated AFCP, i.e., under anticipated poor weather and low capacity. Under normal weather and capacity conditions, little is to be gained by reducing the notification time, for the capacity estimates are relatively certain. It is recommended that the CFCF ascertain whether the estimated capacity is subject to substantial revision during the day and decide on the need for reduced notification time.

The February 5 JFK data are a good example of reduced-capacity operation. By shortening the notification time to four hours (i.e., excluding control of flights with ETE greater than three hours), and revising the allocations each hour, it would have been possible to cut in half the aircraft hours lost on February 5. [(14)] This would have been obtained with individual flight dispatching, and the simple prediction scheme employed in the calculation. Both the prediction scheme, and the dispatching method can be improved on in practice; more important is that the reduction in losses is due in no small measure to continued revision of the allocations. Although the same performance could have been achieved by a single, unrevised capacity estimate, [(13)] there is no way to determine in advance what that estimate should be. Continued revision, as conditions change, can achieve the same performance as the best single capacity estimate, with a much less demanding prediction scheme.

Continued revision is possible with the present computer program, for flights more than 75 minutes from ATD. If the 75 minutes is shortened to 60, and revised allocations issued every hour for the four hour period starting four from the issuance, then the present computer program can be used in what is essentially a four hour notification scheme by making allocations for the first of the four hours firm and those for the other three tentative. This may be misleading for centers in zone III, however, who would receive three tentative allocations for the same hour before receiving the final one. To avoid continual revision, it is advisable to issue only two hour's allocation to a center at a time, only the second of which is subject to revision. This would reduce revisions to a minimum and still allow some swapping into the next hour.

As for prediction schemes, only preliminary results were obtained. The calculations were based on the latest actual capacity observations projected ahead four hours. By combining these with predicted weather conditions, it should be possible to obtain better results, on the average, than using the observations alone. Techniques to do this should be investigated systematically, based on extensive data such as the CATER provides. These techniques need not be incorporated into the computer program but should be part of the revised procedures.

The question of equitability for flights with ETE greater than three hours must be considered. Eliminating this traffic from AFCP (i.e., no ground holds assigned) should be done so as to leave ATA slots for those flights, as in the present computer program. The change recommended is the elimination of the issuance of allocations to centers dispatching flights with ETE's greater than three hours; they would be permitted to depart as scheduled (or later, if desired) and delay in the New York airspace as determined by FCFS. Figure 25 shows that flights so treated would have actually experienced less air delay than they received on February 5 and those assigned 0 hour air delay (ETE's less than three hours) would have actually experienced average air delays of about 30 minutes. This equalization phenomenon can be explained and may be exploited. Parametric studies can be made to select an assigned air delay for different demand-capacity conditions such that the resulting average air delays are a uniform function of ETE. This will produce equitability of air delay but ground delays for only those flights with ETE less than three hours. Numerous variations on this scheme are possible. If an acceptable one can be found it should be incorporated into the procedures.

Investigate Possible Procedures to Avoid Gross Inequities in AFCP Implementation

The February 5 data (e.g., Figure 20) show excessively long hold times for some long-haul overseas flights and a few flights from Mexico and Alaska. Some were diverted during the AFCP, but were held again upon return after AFCP were cancelled.

Excessive enroute delays can cause capacity losses in New York Center. If the enroute centers could identify AFCP flights easily and directly they could assist in reducing the enroute delays of AFCP flights. Such means as tagging the flights should be investigated.

Initiate Better Record Keeping Procedures on AFCP Days

All flow control records and flight strips, during an AFCP period, should be segregated and documented for possible flow control analysis at a later day. The February 5, 1971 records were incomplete; (34) some flight strips were not marked, and with the exception of a few centers it was difficult to ascertain an AFCP delay. AFCP flights should be identified by the station and center of departure to assure that there is no enroute delay, and AFCP ground delays should be noted.

All flights cancelled during AFCP should be identified and that information passed on to the flow controller at CFCF and the ARO. The regulation should be rewritten to place responsibility for notification of cancellation on the air carrier involved and on the center of departure, or in the case of a change enroute, on the center concerned. An effort should be made to record accurate capacity figures for the airports involved so that the AFCP operational authority can make a valid judgment based on adequate historical information. (If the capacity figure changes before and during AFCP it should be quickly cranked into a revised quota system and publicized.)

Tower records of landings and take-offs during an AFCP period should separate AFCP involved aircraft from non-interfering aircraft. If an aircraft is an interfering type, it should be so noted by tower personnel and a reason given for its landing out of the AFCP system.

Initiate a Re-education Program

It was surmised by the TSC investigators, and by the NAFEC data preparation group, that not all ARTC center flow control personnel were completely familiar with the AFCP. ZNY personnel frequently expressed curiosity as to the contents of the KC computer program. The $(CF)^2$ log for February 5 contains the following entry at 1405 GMT:

"We have received in the last 15 minutes many inquiries from the facilities on the Western Conference Loop on the status of AFCP's and various questions on how it is operated. If it is effective at EWR? When do we get hard copies? etc., etc."

The modifications recommended, if incorporated, would make a re-education program even more necessary. A tour of the $(CF)^2$ computer facility, accompanied by a demonstration, would help revive confidence in the computerized procedures.

Use the AFCP Program to Predict Arrival Delays

Perhaps the most important single training device is routine use of the program to produce delay estimates for the users and to build up data on capacity. Checking delay estimates with reports from the centers will build confidence in the program and lead to improvement in it. Also, delay estimates are useful in daily operation.

Drop the 15 Minute Rule

The simulation showed (18) that the first 15 minute rule produces minor variations in the New York arrivals. The examination of the procedures (30) showed that, theoretically, it merely translates the arrival steps that would occur on the hour to quarter after the hour. Moreover, the changes in the allocation interval recommended below makes the rule unnecessary.

III Modify the Program

The program modifications are intended to implement the procedural changes just presented and to overcome some of the impediments to effective operation that were discussed in the previous section.

Expand the Program to Twenty Arrival Terminals

This recommendation is to expand the computer program so that AT may apply the actual procedures to high density terminals other than LGA and JFK as traffic and experience dictate. Even without extension of the actual procedures, this modification will have several advantages. It will allow delay predictions for almost all terminals at which significant delays occur; it will allow CFCF to acquire data on simulated ground holds for HDT's before the procedures are extended to them; it will avoid making a second set of modifications.

One difficulty caused by this change should be recognized. The interaction of traffic among several terminals that are simultaneously under AFCP restrictions may be extensive and should be investigated. Consider, for example, AA 184, which departs LAX, stops at ORD and terminates at LGA. If AFCP applied to LGA requires a one-hour hold at ORD, while its simultaneous application to ORD requires a two-hour hold at LAX, then confusion results. The AFCP holds calculated for LGA traffic must take into account a minimum hold of two hours at ORD for AA 184 and similar flights. If, as is common on the run between DCA and LGA, the same equipment is used in both directions for several flights, then the ground holds are interlocked and a naively programmed algorithm can produce an erroneous answer, or no answer at all. The situation is even more difficult than that of the direct LAX-ORD-LGA flight because it requires information on equipment assignments. The general interaction situation should be investigated to determine (a) what effect it would have on a 20-terminal AFCP system that did not account for it, (b) whether equipment assignment information is needed to remove the problem, and (c) what algorithmic procedure is necessary.

Along with an expansion to more terminals, some subsidiary modifications should be made. The air delay required for initiation and the estimated capacity should be input for each of the terminals. Since these numbers may be different for each terminal, a printout of the nominal and modified values should be made available to the controller. Also, the modifications listed below should be applied to all terminals, but I/O should be limited to those terminals actually under the procedures.

Input Estimated Departure Delays (other than AFCP holds)

The effect of national weather patterns may be partially accounted for by CFCF receiving departure delay estimates from the centers and inserting them into the program. The program should adjust the internal PTD's accordingly.

The Recommended AFCP Start Time should be Calculated for Each Terminal such that the Air Delay at Initiation is Equal to the Desired Maximum Air Delay

The basis for this recommendation is given in the section entitled THE AFCP COMPUTER PROGRAM on page 12 and in the Summary. To facilitate the fifth and sixth recommendations below the start time should be rounded to 00, 20, or 40 minutes after the hour.

Calculate Arrival Slots for All Flights, Regardless of ETE, but Calculate Allocations only from those Flights with ETE's Less than Three Hours

This change implements the procedural change of reduced notification time discussed above.

Draw Allocations from the TATA List by 20-minute Intervals, Excluding Flights with ETE's Greater than Three Hours

This change will smooth out the arrival waves that can come from hourly allocations, as was apparent in the simulation and in the analysis of the procedures. Synchronizing the AFCP initiation time with the start of one of those 20-minute intervals will make it possible to control the air delay at initiation and to draw fairly correct allocations directly from the TATA list.

An alternative to issuing 20-minute allocation to all centers is to issue 60-minute allocations, but to stagger the start of the allocation hour among three groups of centers, one at twenty minutes before the hour, one on the hour, and one twenty minutes after the hour. Such a method is easy to implement with little change in the present program other than initiation time.

Four Hours Prior to the Start of the AFCP Period, Issue Allocations for the First Six 20-minute Arrival Intervals

The allocations for the first hour should be firm (unalterable), except for swapping, but those for the second three intervals should be tentative. This will reduce the notification time to four hours, and allow revision of the allocations every hour, but no more often. As discussed above and recommended below, revision of the allocations every hour is highly desirable. The second, tentative, hour of allocations provides some advance notice and facilitates swapping.

Reissue Allocations at One-Hour Intervals from Initiation Time

Issuances should cover two hours, the first of which is a firm set of allocations, the second of which is tentative. It should be noted that, since initiation need not occur on the hour, the allocation hour need not coincide with GMT hours.

IV Investigate Questions Arising in the Present Study

Improved Methods of Landing Capacity Prediction

It was not possible in the present study to devise better methods of predicting landing capacity, because of the scope and special nature of that problem. Both automatic and semi-automatic methods of prediction should be investigated because these hold greater promise for flow control than techniques based on pure experience. In fact, the lessons of experience can also be incorporated into an automated prediction program through empirical constants derived from historical data. The accumulation of actual landing data in computer-readable form under the CATER program now allows for the first time the development of a thoroughly validated landing capacity prediction theory.

Interaction of Multiple Terminals Under AFCP

This problem and a method of approach was described in connection with the recommendation for expanding the computer program.

Methods of Improving the Equitability of Delay Distribution

If notification time is to be reduced by restricting allocations to the nearer centers, then it does not turn out that the shorter flights have no air delay at arrival, and the farther flights take their normal air delay. Because of first-come-first-served (FCFS), the longer flights are served somewhat earlier than would normally occur, and the short range flights sustain a non-zero air delay. The exact air delays for the two groups depend on the schedule, the proportion of flights in each group, the landing capacity, and the assigned air delay for short range flights. The second and the last of these are under ATC control. By adjusting them, for given capacity and demand, it is possible to control the distribution of air delay between the two groups. In particular, it should be possible to obtain equal air delay for both groups. This is not necessarily equitable, however, since the shorter range flights will receive larger average ground delays. Because of this and other complications it is necessary first to obtain answers to questions such as:

- What is the relative weight of ground hold time to air hold time? Can enroute air holds be substituted for ground holds?
- Is it practical to distinguish flights within and without AFCP and to give landing priority to flights within AFCP control and enroute holds to flights outside of AFCP control?
- What is the precise definition of equitability?

When generally accepted answers to such questions are available, calculations of effectiveness and equitability can be carried out using a variety of demand/capacity samples for several airports. Different suggested solutions can then be evaluated, and measures of equitability and effectiveness obtained. Such a study will provide much of the information needed by the FAA and the users in devising an equitable and effective set of procedures.

CROSS REFERENCES FOR FINDINGS AND RECOMMENDATIONS SECTION

CROSS REFERENCES FOR FINDINGS AND RECOMMENDATIONS SECTION (Cont.)

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ACKNOWLEDGMENTS

The authors wish to acknowledge the substantial contributions to the simulation made by Julie Sussman, who also contributed to its description in section entitled Simulation Study. The authors wish to express their appreciation to:

- Leo J. Mulry and Willard O. Bethel, NAFEC, for processing and reducing to computer form the flight strips used in the case study.
- Personnel of the NYARTCC and the CIFRR who provided background and operational data for the case study.
- Lonnie D. Parrish and the controllers of the CFCF for information and assistance in understanding and analyzing the AFCP.
- The numerous personnel of the Air Traffic Service at FAA Headquarters who provided operational and technical inputs.
- The personnel of MITRE Corporation's Washington, D. C. Operations for information and documentation on the computer program.

Special thanks are due to Thomas E. Armour and Paul H. Petersen of SRDS and Charles E. Dowling, Jr. of OSEM for providing the initial impetus for the project and for continuous assistance and guidance in carrying it out.

APPENDIX A

FAA ORDERS RELATING TO AFCP

ORDER

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

7230.9A

12/19/68

SUBJ: **ADVANCED FLOW CONTROL PROCEDURES (AFCPS)**

1. PURPOSE. This Order sets forth the special procedures to be applied when advanced flow control restrictions (AFCRs) messages are received.

2. EFFECTIVE DATE. This Order is effective immediately.

3. REFERENCE. 7230.1, Facility Operation Handbook.

4. CANCELLATION. This Order cancels and supersedes Order 7230.9, dated 10/14/68 and GENOT Notice N 7230.84, dated 11/13/68.

5. BACKGROUND.

   a. AFCPs have been developed to offset present conditions that result from aircraft converging on critical terminals at higher demand rates than can possibly be accommodated under existing airport resources. This condition is particularly prevalent in the New York metropolitan area during peak traffic hours. When the New York Center airspace becomes saturated, they must resort to stop-and-go flow control techniques which back up traffic into the surrounding centers' areas. This condition makes it almost impossible to move traffic through the affected areas and even more difficult for New York Center to assign accurate delay times.

   b. The stop-and-go flow control technique is always after-the-fact and is not conducive to good traffic planning on the part of users or the air traffic control facilities so affected. The overall effect of such conditions is a breakdown of the orderly and expeditious flow of traffic not only into and out of the New York metropolitan area, but sometimes throughout the eastern United States, parts of Europe, Canada, and the South Atlantic area.

6. GENERAL. AFCPs have been developed to provide the ATC system and its users with some reasonable degree of arrival delay prediction in high density terminal areas. The procedures are to be implemented in advance to become effective during peak traffic hours in designated terminals.

24475

Distribution: FAT-0 (1-5); AT 7230

Initiated By: AT-330

a. AFCPs will initially be implemented for the following New York metropolitan airports: John F. Kennedy (JFK), LaGuardia (LGA) and Newark (EWR).

b. Definitions to be used in this Order.

(1) Assigned Time of Departure (ATD). The departure time assigned by the flow controller and issued to the aircraft pilot or operator. This is determined by subtracting ETE from ATA or PTA, whichever is applicable. An ATD shall always be assigned when AFCRs are in effect, even though it may be the same as the PTD. The ATD should never be earlier than the PTD.

(2) Proposed Time of Departure (PTD). The time the aircraft proposes to depart as filed by pilot or operator in the flight plan.

(3) Estimated Time En Route (ETE). The estimated flying time from departure airport to destination.

(4) Proposed Time of Arrival (PTA). The time the pilot/operator proposes to arrive at destination (PTD + ETE = PTA).

(5) Assigned Time of Arrival (ATA). The time assigned for arrival at destination. ATA's should always be 15 minutes after the hour, unless the PTA is after that time and within the hour, e.g., in the 2200 hour, all ATA's should normally be 2215. ATA's are assigned only when the departure demand exceeds the ARTCC quota.

c. It is expected that other high density airports will be designated for application of AFCPs in the near future. Subsequent designations will be made by the ATC Operations and Procedures Division at Washington Headquarters.

7. PROCEDURAL CONCEPT. AFCPs are designed to:

a. Hold aircraft on ground at departure points to absorb arrival delays in excess of one hour.

b. Distribute delays equitably among all users.

c. Eliminate holding of traffic destined for EWR, LGA, or JFK in other than New York Center's airspace. (International traffic in Boston or Washington Center's area is excepted.)

d. Limit holding in New York Center's area to one hour (or less, provided sufficient demand can be maintained on the ATC system to preclude unnecessary gaps in the arrival sequence).

8. RECEIVING AIR ROUTE TRAFFIC CONTROL CENTER'S (INCLUDING NEW YORK) RESPONSIBILITIES.

a. Provide the flow controller with a duplicate strip for each proposed flight originating in your area and destined for EWR, LGA, and JFK airports. The duplicate strips shall contain at least the following:

(1) Aircraft identification.

(2) Departure point.

(3) Destination.

(4) Proposed time of departure (PTD).

(5) Estimated time en route or proposed time of arrival (PTA).

b. The flow controller shall set up and maintain a sequence board as follows:

(1) For EWR, LGA, and JFK airports.

(2) Sequence in order of PTA.

c. Upon receipt of AFCR message, the flow controllers in all zones shall notify their respective flight service stations that AFCRs are in effect for aircraft destined for EWR, LGA, and JFK airports and specify maximum ground delays for each hour as noted on AFCR messages. This may be done via Service B or Service F at the option of the center. If Service B is used, the message must be in text form and not tabulated. (See Appendixes 1 and 2 for zones and AFCR message formats.) The flow controller shall also notify the terminals that generate traffic for the three named airports.

(1) Air carrier operations will be notified of this information by New York Center through Aeronautical Radio Incorporated at New York.

(2) This early notification is only to alert users that they may experience a ground delay; specific delays will not be

known until assigned time of departure (ATD has been computed).

d. The flow controller shall use the following as a basis in computing ATD and assigned time of arrival (ATA):

(1) Each hour shall commence on the hour and end at 59 minutes past the hour.

(2) The PTA will determine the order of release for departures, regardless of the PTD. If PTA's are the same, then use PTD's to determine the precedence of departures within each group or hour (resolve identical flights equitably).

(a) Compute PTA by adding estimated time en route (ETE) to PTD as filed by operator or pilot.

(b) Group and sequence flights by their PTA for each hour.

(3) Assign ATA's after referring to AFCRs for hourly quotas. (Assign times of arrival so that the flight will arrive at destination at least 15 minutes after the beginning of the assigned arrival hour.) The ATA will be the same as the PTA for those aircraft within the hourly quota who have PTA's beyond 15 minutes after the hour.

(4) Subtract ETE from ATA or PTA, whichever is applicable, to determine ATD. (See Appendix 3 for sample of above.)

(5) The operator of an aircraft may substitute a flight with a later ATD for one with an earlier ATD at his discretion; i.e., a carrier may decide to cancel an earlier flight and substitute a later flight in that spot.

(6) The operator or pilot may wish to absorb ground delay at other than the departure airport and still retain his original ATD. This is permissable provided the delay is taken at an airport within the departure center's area of jurisdiction. The only exceptions permitted are if a noise abatement curfew exists or if the weather forecast indicates that the departure airport will go below minimums or will be closed due to accumulation of precipitation on the runway which would result in cancellation of the flight if ATD is complied with, the operators or pilots who have been assigned departure times (ATD's) may wish to depart either on original departure time

to take delay in the departure center's airspace or refile to an intermediate airport outside departure center's area to absorb the ground delay. This is permissible only at the original departure airport. The assigned time of arrival (ATA) shall remain the same; however, the ATD will change since the time en route (ETE) will be different from the new departure point. The ATA is the responsibility of the original departure center and shall be forwarded in remarks of the flight plan. The AFCR allocation is charged to the original departure center and does not use the intermediate center's allocation.

(7) Aircraft must be ready to depart within plus or minus 15 minutes of the ATD given unless otherwise instructed or restricted by ATC. Controllers are urged to use reasonable judgment before reallocating slots under this provision. (It is the responsibility of the operator or pilot to make good an ATD.) When the pilot or operator advises that maintenance difficulties will not permit takeoff within the ATD plus 15 minutes, the aircraft will be reissued an ATD which shall be the original ATD plus 30 minutes. This will insure that the aircraft will reach the destination pattern within the originally computed ATA hour. If the maintenance difficulties are such that the pilot will be unable to make good the new ATD, his ATD slot should be offered to the first aircraft in the subsequent hour. If such substitution is feasible, assign the aircraft with maintenance problems the vacated ATD in the next hour. If substitution is not feasible, sequence the aircraft with maintenance problems after the last ATD for the subsequent hour.

e. Computations shall be continued throughout the day as long as the restrictions apply to the center.

f. Aircraft pilots or operators shall be advised of the ATD at least one hour prior to the PTD, but not more than 1½ hours in advance. Always assign an ATD even if it is the same as the PTD. Never assign an ATD earlier than the PTD.

g. Communications with the airline companies shall be as follows:

(1) Always provide the ATD's for all scheduled air carriers on the ARINC circuit.

(2) In addition provide the ATD's to the scheduled air carrier company at the departure airport via interphone unless they advise they do not require it.

h. Composite (VFR-IFR) and air file IFR flight plans shall be handled the same as departures from the center's area. The center in whose area the IFR flight originates shall issue holding instructions within its own airspace and issue an expect further clearance (EFC) time computed in the same manner as for a departure. If the pilot wishes to land and absorb the delay at an airport within the same center area; he may do so. The EFC then becomes the ATD.

i. AFCRs will be issued individually for each of the New York airports (EWR, LGA, or JFK); therefore, each airport is to be considered individually; that is, when an AFCR has been issued for JFK only, then no AFCRs apply for either EWR or LGA.

j. When AFCRs are in effect, the clearance issued to the terminal should always include a "release not before________(time)." This release time is the earliest time that the aircraft is permitted to depart the runway (ATD minus 15 minutes).

9. FSS RESPONSIBILITY. Upon receipt of an IFR flight plan destined for JFK, LGA, or EWR, take the following action:

a. Advise the pilot/operator there may be a ground delay and request the pilot call back one hour prior to estimated time of departure for an ATD. (If the FSS has received the AFCR notification giving maximum ground delays, so advise the pilot.) If the airport of departure is not within the area of control for that flight service station, the pilot/operator shall be advised to contact the FSS or center having responsibility for that airport for his ATD.

b. Transmit the flight plan to the center of jurisdiction and request an ATD.

c. When center issues ATD, retain this information until pilot calls for it.

d. Advise the center immediately if an ATD or a request for an ATD is canceled.

e. Upon receipt of a VFR flight plan destined for JFK, EWR, or LGA, advise the pilot of the current or forecasted delays as indicated in the NOTAM or AFCR. Advise the pilot that the New York terminal facility will provide the delay for his aircraft on initial contact. This delay could be that which is being incurred by the IFR aircraft for that airport.

10. <u>TERMINAL PROCEDURES</u>. When the ARTCC advises that AFCRs are in effect for JFK, LGA, or EWR, take the following action.

a. Always obtain clearance from ARTCC with release time. This release time should be "release not before__________(time)."

b. To the extent possible, plan ground movement of aircraft destined for the above named airports so that they can make good the time specified in paragraph 10.a. above.

11. <u>IMPLEMENTATION</u>. AFCPs are effective December 15, 1968; however, there will be periods of time when traffic conditions do not require activation of the procedures. It therefore may become necessary to conduct training or simulation exercises in order to maintain proficiency in the application of these procedures. When training exercises are conducted, messages shall contain the word "simulation" at the beginning and end of each message. When AFCR "simulation" messages are received, each center shall simulate their functions accordingly, including processing strips and assigning ATD's; however, notification to user agencies, FSS's and terminals shall not be done. Training exercises are to be conducted only within the centers. Any problem areas which occur during training periods shall be submitted to the New York ARTCC and Washington Headquarters, AT-300, for resolution.

12. <u>MISCELLANEOUS</u>.

a. The enclosed procedures represent an initial agency effort to promote a more orderly flow of traffic into a major terminal area through an upgrading of flow control procedures. The success of this effort rests squarely on the facilities that will administer the procedures; therefore, we request your cooperation and forbearance in making the procedures work.

b. The procedures contained in Part 900 of 7230.1 remain in effect as supplemental procedures during the period when AFCRs are implemented.

c. Ground delays are issued for the purpose of indicating to users that if planning to arrive at EWR, LGA, or JFK during the hours AFCRs are in effect they may incur up to that amount of ground delay. The hours indicated on the AFCR message pertain to arrival times at destination. The flight may encounter no delay if included in the quota to arrive at that hour.

d. Maximum ground delays are also an indication to the flow controller as to the effectiveness of the AFCRs.

e. If ground delays become appreciably higher than the maximum ground delays shown on the AFCR message, the New York flow controller should be advised via the most expeditious means. When making such notification, state the reason (if known); i.e., excessive departure delays at departure point or significantly more aircraft than the quota allowed.

f. Also, advise the New York flow controller as far in advance as possible of any known or predictable increase or decrease in traffic that would affect the assigned quotas.

g. The following have been designated as coordination centers for their respective groups:

New York Center:	All of Zone I and IV
Houston :	Houston, Miami, Memphis and Ft. Worth
Kansas City :	Kansas City, Denver and Minneapolis
Oakland :	All of Zone III

Each coordination center shall be responsible for release of or request for additional quotas among the centers within its group. It shall be the sole responsibility of the coordination centers to request additional quotas on the basis that there are aircraft which exceed the maximum ground delay as specified in the AFCR message. It shall also be the sole responsibility of the coordination center to reallocate surplus quotas within its designated group. In the event quotas can be released or additional quotas are needed by the group, the coordination center shall contact the New York Center with such release or request. All centers shall release unused quotas for a particular hour as soon as ATD's for that hour have been assigned. The users have been requested to file IFR flight plans at least 1½ hours prior to proposed departure when destined for JFK, LGA, and EWR. Therefore, the following policy has been established:

(1) If the user changes to new destination, the assigned ATD is cancelled except as specified under paragraph 8.d(6) above.

(2) If the AFCR is in effect at only one of the New York airports, the pilot or operator may change destination to one of the other above named airports without the 1½ hour advance filing.

(3) If the flight plan is not received in the center prior to the assignment of ATD's for a particular hour, the late flight should be included in the computation for the subsequent hour.

h. Facility Chiefs or their designated representative shall personally monitor this program to ensure complete understanding and application of the procedures.

William M. Flener

William M. Flener
Director, Air Traffic Service

APPENDIX 1. CENTERS

1. ZONE I.

    a. Boston
    b. New York*
    c. Washington
    d. Jacksonville
    e. Cleveland
    f. Chicago
    g. Indianapolis
    h. Atlanta
    i. Canada - Montreal and Toronto

2. ZONE II.

    a. Houston*
    b. Miami
    c. Memphis
    d. Ft. Worth
    e. Kansas City*
    f. Denver
    g. Minneapolis

3. ZONE III.

    a. Albuquerque
    b. Los Angeles
    c. Salt Lake City
    d. Great Falls
    e. Seattle
    f. Oakland*

4. ZONE IV.

    a. Bermuda
    b. European Area
    c. All other areas not included in ZONES I, II, and III.

* indicates Coordination Center

APPENDIX 2. SAMPLE ADVANCED FLOW CONTROL RESTRICTION MESSAGES

Addresses: All ZONE I Centers
LGA, BOS, DCA, JAX, CLE, CHI, ATL, IND, UL, YZ

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z.

JFK	BOS	DCA	JAX	CLE	CHI	ATL	IND	UL	YZ	MAX GRND. DELAY
2000-2059Z	4	1	0	1	1	1	1	1	0	:40 min.
2100-2159Z	4	1	0	1	2	0	0	0	0	1:20
2200-2259Z	4	1	1	2	2	1	0	0	0	1:40
2300-2359Z	4	2	1	1	1	1	0	0	1	1:40
0000-0059Z	4	2	0	2	2	0	0	1	0	2:00
0100-0159Z	4	2	0	3	1	1	0	0	1	2:02
0200-0259Z	4	1	1	1	1	1	1	1	0	1:50
0300-0359Z	4	2	1	2	1	1	1	0	1	1:00

Void 170400Z ZNY 161700Z

Addresses: All ZONE II Centers
MIA, HOU, FTW, MEM, MKC, MSP, DEN

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z

JFK	MIA	HOU	FTW	MEM	MKC	MSP	DEN	MAX GRND. DELAY
2000-2059Z	3	2	1	1	0	0	0	:40 min.
2100-2159Z	3	1	1	0	0	0	1	1:20
2200-2259Z	2	0	1	0	0	1	1	1:40
2300-2359Z	3	1	1	0	1	1	0	1:40

JFK	MIA	HOU	FTW	MEM	MKC	MSP	DEN	MAX GRND. DELAY
0000-0059Z	3	1	1	0	1	0	0	2:00
0100-0159Z	2	1	1	0	0	0	0	2:02
0200-0259Z	2	1	1	1	0	1	0	1:50
0300-0359Z	2	1	1	0	1	1	0	1:00

Void 160400Z ZNY 161500Z

Addresses: All ZONE III Centers
ABQ, LAX, SLC, SEA, OAK, GTF

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z.

JFK	ABQ	LAX	SLC	SEA	OAK	GTF	MAX GRND. DELAY
2000-2059Z	2	1	0	2	1	0	:40 min
2100-2159Z	0	2	0	0	3	0	1:20
2200-2259Z	0	2	0	1	2	0	1:40
2300-2359Z	0	3	0	0	1	0	1:40
0000-0059Z	0	2	0	0	3	0	2:00
0100-0159Z	0	3	0	0	1	0	2:02
0200-0259Z	1	1	0	0	2	0	1:50
0300-0359Z	0	1	0	0	1	0	1:00

Void 160400Z ZNY 161200Z

APPENDIX 3. SAMPLE ASSIGNMENTS

		Proposed Departure Time (PTD)	Assigned Departure Time (ATD)	Proposed Arrival Time (PTA)	Estimated Time En Route (ETE)	Assigned Arrival Time (ATA)	Ground Delay
AA-1	CHI-JFK	P1830	1830	2020	1 + 50	2020	:00
TW-2	CHI-JFK	P1832	1927	2020	1 + 48	2115	0:55
UA-3	CHI-JFK	P1915	2020	2110	1 + 55	2215	1:05
N-123	CHI-JFK	P1600	1600	2140	5 + 40	2140	:00
EA-45	CHI-JFK	P1935	1940	2205	2 + 30	2215	0:05
NW-40	CHI-JFK	P2025	2130	2210	1 + 45	2315	1:05
AA-6	CHI-JFK	P2025	2225	2215	1 + 50	0015	2:00
N-445	CHI-JFK	P2000	2155	2220	2 + 20	0015	1:55

SUBJ: ADVANCED FLOW CONTROL IMPLEMENTING PROCEDURES

1. PURPOSE. This Order sets forth the criteria and special procedures to be applied by the New York Air Route Traffic Control Center (ARTCC) when implementing advanced flow control restrictions (AFCRs).

2. EFFECTIVE DATE. This Order is effective October 27, 1968, for simulation purposes and November 15, 1968, for operational purposes.

3. REFERENCES.

a. 7230.1, Facility Operation Handbook.

b. Official Airline Guide.

c. Order 7230.9, Advanced Flow Control Procedures (AFCPs).

4. GENERAL.

a. AFCPs are designed to be implemented during peak traffic hours to hold aircraft on the ground at points of departure until the air traffic control system can safely and expeditiously accommodate them. These procedures are not meant to get more aircraft on the ground, but to meter the traffic into the terminal areas in an orderly fashion.

b. The mechanics of advanced flow control are very basic. The arrival center will determine the hourly demand on their terminal by referring to the Official Airline Guide and by statistical history of past operations for general aviation data. The center will then determine an acceptance rate for the terminal based on forecast weather and runway configuration. This information will be combined to determine what hours the demand will exceed the acceptance rate. Where the demand is forecasted to exceed the acceptance rate, an advanced flow control message will be issued which will allocate slots to each feeding center and thus regulate the flow of traffic into the affected terminal so as not to exceed one hour holding in the terminal area. Users will be notified of the amount of ground delay that can be expected at least one hour before the original estimated time of departure.

23541

Distribution: AT 7230; FAT-0 (1 cy);
New York ARTCC - 25 copies

Initiated By: AT-320

c. AFCPs will initially be implemented for John F. Kennedy (JFK), LaGuardia (LGA), and Newark (EWR) Airports.

d. Subsequent designations will be made by the ATC Operations and Procedures Division at Washington Headquarters.

5. DEFINITIONS. The definitions as used herein apply only to AFCPs.

a. Demand Rate--The number of hourly operations anticipated at an airport when based on schedules, statistical history, flight plans, and other data sources as necessary to obtain this information.

b. Acceptance Rate--The hourly capacity of an airport to accommodate interfering arrivals when such variables as weather conditions, runway configuration, spacing interval, or other pertinent conditions have been considered.

c. Acceptance Rate Profile--A chart depicting the hourly ratio of demand rate to acceptance rate and used by the implementing flow controller as a basis for allocation of release quotas to feeding centers.

d. Interfering Operation--Any IFR or VFR operation that utilizes the active IFR runway or runways and affects the acceptance rate.

6. PROCEDURAL CONCEPT. AFCPs are designed to:

a. Hold aircraft on ground at departure points to absorb arrival delays in excess of one hour.

b. Distribute delays equitably among all users.

c. Eliminate random holding in all but the New York Center's area for traffic destined for JFK, LGA, or EWR.

d. Limit holding in the New York Center's area to one hour (or less provided sufficient demand can be maintained on the ATC system to preclude unnecessary gaps in the arrival sequence).

e. Meter the flow of arrival traffic into high density terminal areas in an orderly manner without saturating the en route environment.

7. TRANSMITTING ARTCC (NEW YORK ONLY) RESPONSIBILITIES. The New York ARTCC shall take the following action:

a. Develop and update as necessary a Flow Control Handbook containing at least the following data:

(1) Current demand rate charts for JFK, LGA, and EWR Airports.

(2) Acceptance rate charts--as many as necessary to reflect interfering operations for all runway configurations for each affected airport.

(3) Acceptance rate profile charts--as many as necessary for various acceptance rates.

(4) Zone charts and sample messages--see Appendixes 1 and 2.

(5) Other data or instructions as necessary.

b. The 0000 through 0800 (local time) flow controller shall take the following action:

(1) By referring to demand rate charts (modified as necessary when there is reason to believe there will be an increase or decrease in traffic), checking weather forecasts, conferring with approach control for airport conditions and anticipated runway configurations, determine if AFCRs will be required for the period 0800 through 2359 (local time).

(2) Initiate AFCRs only for periods when arrival delays are anticipated to reach one hour; i.e., a backlog of one hours traffic as determined by referring to the acceptance rate profile chart.

(3) The acceptance rate for the affected period shall be decided upon after consultation with the approach control facility.

(4) When it has been determined that AFCRs are necessary, refer to the appropriate acceptance rate profile chart and issue AFCR messages to concerned centers via Service B as far in advance as practical, but in no case less than the following:

(a) Zone I--Four hours before aircraft are scheduled to arrive at destination.

(b) Zone II--Six hours before aircraft are scheduled to arrive at destination.

(c) Zone III--Eight hours before aircraft are scheduled to arrive at destination.

(d) Zone IV--Two hours before effective at destination. (New York Oceanic Control will maintain and advise Boston of EFCs for international flights.)

(5) AFCRs may be issued all at once or at different times by zones provided minimum advance times in (4), above, are adhered to. If issued at different times, specify status for other zones.

(6) Issue maximum ground delay times and allocations to air carriers via Aeronautical Radio Incorporated.

(7) Issue NOTAMs to inform users that AFCRs are in effect and to refer to the Airman's Information Manual for procedures.

c. Flow controllers on duty after 0800 (local time) shall take the following actions:

(1) Revise or cancel original AFCRs as necessary after considering updated weather forecasts, revised demand rates, or acceptance rates.

(2) Revise allocation rates by zones as necessary to increase or decrease traffic within orderly limits.

(3) Monitor feeder stacks and coordinate with approach control to confirm acceptance rates.

(4) Utilize "hot line" to monitor conditions in other surrounding center's area as they relate to New York traffic.

8. IMPLEMENTATION. AFCPs will be implemented on a simulated basis on October 27, 1968, and operationally implemented on November 15, 1968. The simulated period is being conducted as a training exercise to preclude any major problem areas that may occur later. Issue simulated messages and implement procedures making sure all concerned understand it is "simulated." State "simulated AFCR" verbally or note on all messages during the training period. Any problem areas that occur should be brought to the attention of the ATC Operations and Procedures team assigned at the New York Center during simulation.

9. MISCELLANEOUS.

a. The enclosed procedures represent an initial agency effort to upgrade flow control procedures. The success of these procedures will rely to a large degree on the experience and judgment of the flow controller. For this reason, flow controllers shall become thoroughly familiar with these procedures prior to implementation.

b. The procedures contained in Part 900 of 7230.1 remain in effect as supplemental procedures during the period when AFCRs are implemented.

c. When information is received from several centers that ground delays are appreciably higher than advertised, revise ground delays. If only one or two centers are involved, review operations to allow for possible adjustments if feasible.

Lewis J. Howland

fn William M. Flener
Acting Director
Air Traffic Service

APPENDIX 1. CENTERS

1. ZONE I.

   a. Boston
   b. New York
   c. Washington
   d. Jacksonville
   e. Cleveland
   f. Chicago
   g. Indianapolis
   h. Atlanta
   i. Canada (eastern area)
   j. Bermuda

2. ZONE II.

   a. Miami
   b. Houston
   c. Memphis
   d. Kansas City
   e. Minneapolis
   f. Denver
   g. Fort Worth

3. ZONE III.

   a. Albuquerque
   b. Los Angeles
   c. Salt Lake City
   d. Great Falls
   e. Seattle
   f. Oakland

4. ZONE IV.

   a. European area
   b. South Atlantic area and Mexico

APPENDIX 2. SAMPLE ADVANCED FLOW CONTROL RESTRICTION MESSAGES

Addresses: All Zone I Centers
BOS, DCA, JAX, CLE, CHI, ATL, IND, UL, YZ, BDA

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z.

JFK	BOS	DCA	JAX	CLE	CHI	ATL	IND	UL	YZ	BDA	MAX GRND DLY
2000-2059Z	4	1	0	1	1	1	1	1	0	1	:40 min.
2100-2159Z	4	1	0	1	2	0	0	0	0	1	1:20
2200-2259Z	4	1	1	2	2	1	0	0	0	0	1:40
2300-2359Z	4	2	1	1	1	1	0	0	1	0	1:40
0000-0059Z	4	2	0	2	2	0	0	1	0	1	2:00
0100-0159Z	4	2	0	3	1	1	0	0	1	0	2+02
0200-0259Z	4	1	1	1	1	1	1	1		1	1+50
0300-0359Z	4	2	1	2	1	1	1	0	1	1	1+00

Void 1704000Z ZNY 161700Z

Addresses: All Zone II Centers
MIA, HOU, FTW, MEM, KCK, MSP DEN

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z.

JFK	MIA	HOU	FTW	MEM	KCK	MSP	DEN	MAX GRND DLY
2000-2059Z	3	2	1	1	0	0	0	:40 min.
2100-2159Z	3	1	1	0	0	0	1	1:20
2200-2259Z	2	0	1	0	0	1	1	1:40
2300-2359Z	3	1	1	0	1	1	0	1:40

JFK	MIA	HOU	FTW	MEM	KCK	MSP	DEN	MAX GRND DLY
0000-0059Z	3	1	1	0	1	0	0	2:00
0100-0159Z	2	1	1	0	0	0	0	2+02
0200-0259Z	2	1	1	1	0	1	0	1+50
0300-0359Z	2	1	1	0	1	1	0	1+00

Void 160400Z ZNY 161500Z

Addresses: All Zone III Centers
ABQ, LAX, SLC, SEA, OAK, GFL

Advanced flow control restrictions for aircraft scheduled to arrive JFK between the hours of 162000Z - 170400Z.

JFK	ABQ	LAX	SLC	SEA	OAK	GFL	MAX GRND DLY
2000-2059Z	2	1	0	2	1	0	:40 min
2100-2159Z	0	2	0	0	3	0	1:20
2200-2259Z	0	2	0	1	2	0	1:40
2300-2359Z	0	3	0	0	1	0	1:40
0000-0059Z	0	2	0	0	3	0	2:00
0100-0159Z	0	3	0	0	1	0	2+02
0200-0259Z	1	1	0	0	2	0	1+50
0300-0359Z	0	1	0	0	1	0	1+00

Void 160400Z ZNY 161200Z

ORDER

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

7230.11

12/19/68

SUBJ: ADVANCED FLOW CONTROL PROCEDURES (AFCPS) FOR INTERNATIONAL FLIGHTS

1. PURPOSE. This Order sets forth the procedures to be applied by the New York, Boston, and Washington Air Route Traffic Control Centers for international flights (Zone IV) that will transit the respective areas en route to the John F. Kennedy (JFK), LaGuardia (LGA), or Newark (EWR) Airports when advanced flow control restrictions (AFCRs) are in effect. These procedures are in addition to the procedures contained in Orders 7230.9A and 7230.10.

2. EFFECTIVE DATE. This Order is effective December 15, 1968.

3. REFERENCES.

   a. Order 7230.9A, Advanced Flow Control Procedures (AFCPs).

   b. Order 7230.10, Advanced Flow Control Implementing Procedures.

4. GENERAL.

   a. AFCPs have been designed to distribute delays equitably among all users by holding aircraft on the ground at their departure points. The exceptions to this are the international flights en route to New York metropolitan airports from points outside the continental United States.

   b. Since no provisions have been made for ground holding of international flights (Zone IV), the following procedures have been developed for application by the New York, Boston, and Washington Centers. The procedures are designed to retain the equitable distribution of delays but differ in concept by permitting optional ground holding at an intermediate point en route (instead of airborne holding to absorb delays in excess of one hour) while retaining the original expect further clearance (EFC) times just as though no landing had been made.

5. RESPONSIBILITIES.

   a. Establish or designate, as necessary, high altitude delay absorbing patterns in which to hold international traffic (Zone IV) en route to JFK, LGA, or EWR.

24474

Distribution: AT 7230; FAT-0 (1 cy); New York ARTCC - 25 copies; Washington ARTCC - 25 copies; Boston ARTCC - 25 copies

Initiated By: AT-320

b. Maintain a separate board on which to sequence international flights en route to the affected airports.

c. Assign these flights EFC times based on the hourly allocations noted on the Zone IV message. (See Appendix 1.)

d. Hold aircraft in excess of quotas in designated delay absorbing patterns and release (in conjunction with EFC) in a manner that will preclude the hourly quota from reaching the handoff fix at one time. A recommended method would be to divide the hourly quota into sixty minutes and assign EFCs and release aircraft based on that interval. (Example. An hourly quota of four aircraft divided into sixty minutes equals a fifteen-minute interval.)

e. Assign EFCs as early as possible after an accurate sequence can be established.

f. Assign the EFC when the aircraft establishes communications with the Washington or Boston Center and in the case of New York Oceanic, one hour prior to entering the New York Center's domestic boundary.

g. Notify the flight (and the operator if so coordinated and agreed to locally) of the EFC in accordance with the time limits in e and f, above.

h. Do not issue an EFC in excess of the maximum holding delays shown in the Zone IV allocation message unless coordinated with and concurred in by the New York flow controller.

i. Protect EFC times of diverting aircraft within plus or minus fifteen minutes of the original EFC.

j. The New York Center shall take steps to determine the routes that North and South Atlantic traffic is flight planning for the day prior to making out the Zone IV allocations.

k. The New York Center shall coordinate as required with the Boston and Washington Centers to ensure that the Zone IV allocations are accurate and revise them as necessary.

l. The Boston and Washington Centers shall advise the New York flow controller as far in advance as possible of any known or predictable increase or decrease in traffic that would affect the assigned quotas.

m. The Boston Center shall coordinate with bordering Canadian air traffic control facilities as necessary to retain the equitable intent of AFCPs as concerns aircraft that have diverted to Canadian airports and, also, to obtain accurate times needed to assign, revise, or protect EFC times.

6. MISCELLANEOUS. If an aircraft overflies the concerned center's area of jurisdiction to land at an airport in another center's area, the flight then becomes part of the domestic quota of the center's area in which it lands. The exceptions to this are when the aircraft are unable to land at an intermediate airport because of weather or an emergency. An example would be a Zone IV flight overflying Boston and New York Centers' areas to land at Dulles Airport. This flight then becomes subject to the Washington domestic quota. An intermediate airport in this case would be any airport along the route prior to reaching the New York domestic control area. In the case of aircraft in the New York oceanic area, an intermediate airport includes airports in the New York, Boston, and Washington areas of jurisdiction.

William M. Flener

William M. Flener
Director, Air Traffic Service

APPENDIX 1. SAMPLE ADVANCED FLOW CONTROL RESTRICTION MESSAGES

Addresses: BOS, ZNY, DCA

Zone IV AFCRs for aircraft scheduled to arrive JFK between the hours of 162000z - 170400z.

JFK	BOS	DCA	ZNY	MAX. HLDG. DLY.
2000 - 2059z	8	0	1	:40
2100 - 2159z	8	1	3	1:20
2200 - 2259z	7	0	3	1:40
2300 - 2359z	7	0	3	1:40
0000 - 0059z	6	1	3	2:00
0100 - 0159z	6	0	5	2:02
0200 - 0259z	4	1	5	1:50
0300 - 0359z	4	0	4	1:00

ORDER

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

7230.11

12/19/68

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   b. Since no provisions have been made for ground holding of international flights (Zone IV), the following procedures have been developed for application by the New York, Boston, and Washington Centers. The procedures are designed to retain the equitable distribution of delays but differ in concept by permitting optional ground holding at an intermediate point en route (instead of airborne holding to absorb delays in excess of one hour) while retaining the original expect further clearance (EFC) times just as though no landing had been made.

5. RESPONSIBILITIES.

   a. Establish or designate, as necessary, high altitude delay absorbing patterns in which to hold international traffic (Zone IV) en route to JFK, LGA, or EWR.

24474

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Initiated By: AT-320

b. Maintain a separate board on which to sequence international flights en route to the affected airports.

c. Assign these flights EFC times based on the hourly allocations noted on the Zone IV message. (See Appendix 1.)

d. Hold aircraft in excess of quotas in designated delay absorbing patterns and release (in conjunction with EFC) in a manner that will preclude the hourly quota from reaching the handoff fix at one time. A recommended method would be to divide the hourly quota into sixty minutes and assign EFCs and release aircraft based on that interval. (Example. An hourly quota of four aircraft divided into sixty minutes equals a fifteen-minute interval.)

e. Assign EFCs as early as possible after an accurate sequence can be established.

f. Assign the EFC when the aircraft establishes communications with the Washington or Boston Center and in the case of New York Oceanic, one hour prior to entering the New York Center's domestic boundary.

g. Notify the flight (and the operator if so coordinated and agreed to locally) of the EFC in accordance with the time limits in e and f, above.

h. Do not issue an EFC in excess of the maximum holding delays shown in the Zone IV allocation message unless coordinated with and concurred in by the New York flow controller.

i. Protect EFC times of diverting aircraft within plus or minus fifteen minutes of the original EFC.

j. The New York Center shall take steps to determine the routes that North and South Atlantic traffic is flight planning for the day prior to making out the Zone IV allocations.

k. The New York Center shall coordinate as required with the Boston and Washington Centers to ensure that the Zone IV allocations are accurate and revise them as necessary.

l. The Boston and Washington Centers shall advise the New York flow controller as far in advance as possible of any known or predictable increase or decrease in traffic that would affect the assigned quotas.

m. The Boston Center shall coordinate with bordering Canadian air traffic control facilities as necessary to retain the equitable intent of AFCPs as concerns aircraft that have diverted to Canadian airports and, also, to obtain accurate times needed to assign, revise, or protect EFC times.

6. MISCELLANEOUS. If an aircraft overflies the concerned center's area of jurisdiction to land at an airport in another center's area, the flight then becomes part of the domestic quota of the center's area in which it lands. The exceptions to this are when the aircraft are unable to land at an intermediate airport because of weather or an emergency. An example would be a Zone IV flight overflying Boston and New York Centers' areas to land at Dulles Airport. This flight then becomes subject to the Washington domestic quota. An intermediate airport in this case would be any airport along the route prior to reaching the New York domestic control area. In the case of aircraft in the New York oceanic area, an intermediate airport includes airports in the New York, Boston, and Washington areas of jurisdiction.

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2100 - 2159z	8	1	3	1:20
2200 - 2259z	7	0	3	1:40
2300 - 2359z	7	0	3	1:40
0000 - 0059z	6	1	3	2:00
0100 - 0159z	6	0	5	2:02
0200 - 0259z	4	1	5	1:50
0300 - 0359z	4	0	4	1:00

AC NO: 90-43A

DATE: 12/23/69

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: OPERATIONS RESERVATIONS FOR HIGH-DENSITY TRAFFIC AIRPORTS

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1. PURPOSE. This circular advises the aviation community of the means for all aircraft operators, except scheduled and supplemental air carriers and scheduled air taxis, to obtain a reservation to operate to and/or from designated high-density traffic airports (HDTAs).

2. CANCELLATION DATE. Advisory Circular 90-43, dated March 25, 1969, is canceled.

3. REFERENCES.

   a. Federal Aviation Regulations (FAR), Part 93, Subpart K.

   b. Airman's Information Manual.

4. DEFINITIONS.

   a. Reservation. An authorization received in compliance with FAR 93 to operate to and/or from a designated HDTA. Reservations are allocated on an hourly basis; however, an approved reservation does not constitute a warranty against traffic delays nor does it guarantee arrival and/or departure within such allocated hour. Such reservations constitute neither an air traffic control clearance nor the filing of required IFR flight plans, nor does the reservation constitute authority to violate any local restrictions. A reservation for a VFR operation constitutes the filing of a VFR flight plan as required by FAR 93.125.

   b. Airport Reservation Office (ARO). A facility operated by the Federal Aviation Administration to administer the issuance of IFR reservations in consonance with FAR 93.

AC 90

Initiated by: AT-320

c. Flow Control. A service whereby the flow of IFR aircraft is regulated or restricted within an affected area or at an altitude stratum to the maximum number of aircraft which can be safely accommodated by the ATC system.

5. DISCUSSION.

a. The FAA, by Part 93, Subpart K, of the FARs, has designated the John F. Kennedy, LaGuardia, Newark, O'Hare, and Washington National Airports as HDTAs and has prescribed air traffic rules and requirements for operating aircraft to and from these airports. Each is limited to the hourly number of allocated IFR operations that may be reserved for the specific classes of users for that airport. Additional operations may be authorized by ATC under certain conditions. An operation between the hours from 6:00 AM to midnight local time may not be conducted to or from these airports unless a departure or arrival reservation has been obtained from ATC and a flight plan has been filed. However, a "mercy flight" involving a medical emergency to or from one of these airports will be handled within the ATC system without regard to the obtainment of a reservation.

b. The FAA has established the ARO to provide IFR reservation service for operations at designated HDTAs. This office processes all IFR requests for reservations. VFR requests are handled procedurally at the HDTA locations and are discussed later.

c. These IFR reservations are allotted on a "first-come-first-served" basis determined by the time the request is received at the reservation office. Standby lists are not maintained. To enable the operator to do his filing during normal business hours on normal business days, requests for a reservation for an IFR operation will be accepted any time after 6:00 AM local time on the day which is 48 hours in advance of the proposed operation. For example, a request for an 11:00 PM operation, as well as a request for a 6:00 AM operation, on a Friday would be accepted any time after 6:00 AM local time on a previous Wednesday. Furthermore, a reservation request for an IFR operation on Monday or Tuesday would be accepted any time after 6:00 AM local time the previous Friday. Additionally, reservation requests for operations during holiday periods will be accepted as listed below:

Days of Operation	Request Accepted After 6:00 AM Local Time
May 31; June 1, 2, 1970	May 28, 1970
July 5, 6, 7, 1970	July 2, 1970

These will be filled within the basic allotments; however, as weather and other factors will determine whether additional reservations in excess of the number allocated may be authorized, IFR requests in excess of the available basic allocation will normally not be approved prior to six hours in advance of the intended operation.

d. An approved reservation does not constitute a warranty against traffic delays. It will be necessary in some instances to issue flow control restrictions which will meter air traffic to the affected airport at a lesser rate than the number for which reservations have been granted. Such system-induced delays which result in a pilot failing to make good his allocated time will not be grounds for cancellation of the reservation. It is also realized that a pilot that has planned his operation shortly after the beginning of an hour may occasionally find himself confronted with a situation whereby his operation is being conducted in the latter portion of the hour prior to the one in which he has his reservation. A pilot in this case need not obtain a new reservation for the hour in which the new operation is being conducted.

e. The ARO will not provide dynamic scheduling. Assignments will be made on an hourly basis; e.g., an approved reservation for 1300 covers an operation any time between 1300 and 1359.

f. The filing of a request for an IFR reservation does not constitute the filing of an IFR flight plan as required by Part 93, Subpart K, of the FARs. The IFR flight plan should be filed only after the reservation is obtained and should be filed through normal channels. The ARO is not equipped to accept or process IFR flight plans.

6. IFR PROCEDURES.

a. A pilot may obtain an IFR reservation in either one of two ways. He may file his request with the nearest FSS by any available means or telephone the ARO direct. If filed with an FSS, the specialist at that time will obtain information on how the pilot is to be notified of the results. Upon contacting the FSS or ARO, a pilot may file arrival, departure and appropriate subsequent departure and arrival reservations with the same request. The telephone numbers for the following cities for direct contact to the ARO are as follows:

(1) Newark, New Jersey 201-645-4370

(2) New York, New York 212-656-4177

(3) Chicago, Illinois 312-372-5215

(4) Washington, D.C. 202-963-5161

These telephone numbers all terminate at the ARO in Washington, D.C. They may be used in the cities indicated for the cost of a local call, or a pilot not located in one of these cities should use the one for the city closest to him to reduce toll charges.

b. When filing his request for an IFR reservation, the pilot should include the following information:

(1) Aircraft identification.

(2) Name/s of high-density airport/s he wishes reservations for.

(3) Proposed departure and/or arrival time/s in Greenwich Mean Time (GMT) as appropriate.

(4) How he may be notified of the result of his request (if filed with an FSS).

(5) Point of departure if other than an HDTA location.

(6) Estimated time en route when inbound to an HDTA location.

c. Should the requested time not be available, the closest available time within a period of six hours after the requested time will be assigned. If no times are available within this period, then the closest available time within a period of six hours before the requested time will be assigned. This will be considered as an assigned allocation unless subsequently canceled by the pilot.

d. Although pilots are encouraged to give cancellations to the ARO or any FSS, an IFR reservation may be canceled with any ATC facility and should include the following information:

(1) Aircraft identification.

(2) The airport for which the allocation was held.

(3) The date and hour (GMT) for which the reservation was granted.

e. A pilot holding an IFR reservation must retain his IFR status until in contact with the terminal facility, otherwise he may be refused VFR handling in accordance with paragraphs 7b through 7e.

f. Reservations are not needed when filing one of the HDTAs as an alternate airport. Pilots are encouraged, however, to file airports other than the HDTAs as alternate airports when possible.

7. VFR PROCEDURES.

a. There will be no advance reservations for VFR arrivals. Unless he has obtained information as provided under paragraph 7c, below, the pilot should proceed toward his intended HDTA destination; however, he should at all times plan an alternate destination in case a reservation is not available upon arrival.

b. Each HDTA terminal facility will handle VFR arrival requests. The pilot, when approximately 30 miles from the HDTA, should airfile his request with the appropriate approach control by stating: "N . . . requesting VFR reservation for (time) arrival for . . . Airport." If a VFR reservation is available, the approach controller will provide the appropriate air traffic control services. If no reservations are available at that particular time, the approach controller will so advise the pilot. The pilot should then proceed to another airport of his choice. A pilot originating his flight within 30 miles of the HDTA may obtain this information within 15 minutes prior to his departure by telephoning the HDTA terminal facility at the number listed in paragraph 7e. Being provided the appropriate air traffic control services by the approach controller constitutes the obtainment of a reservation and the filing of a flight plan as required by FAR 93.129(b) and 93.125(b), respectively.

c. At any time an HDTA facility is not authorizing VFR operations, a notice to airmen to that effect will be issued by that facility. This information can be obtained from any FSS or by referring to the

HDTA teletype report. The code "VA" at the end of the weather report means that "VFR arrival reservations are available" at that particular airport. The code "VA" followed by a condition means that only conditional VFR arrival reservations are available; e.g., "VA 32" means that VFR arrival reservations are available on Runway 32. The code "VNA" means that VFR arrival reservations are not available. These codes will not be used when IFR weather conditions exist.

d. VFR departure reservations, when available, are allotted directly by the HDTA facility. To determine whether VFR departure reservations are available, the pilot should first call the appropriate number as listed in paragraph 7e, below. Upon determining that VFR departure reservations are being granted, he should then contact the control tower on the appropriate frequency for his departure clearance. This contact and the receipt of the departure clearance fulfill the requirement for a VFR flight plan and the obtainment of a reservation as stated in FAR 93.

e. The following locations should be contacted prior to requesting departure clearance or an arrival clearance if originating within 30 miles of the HDTA to determine if VFR reservations are being granted:

(1) O'Hare 312-686-2108

(2) LaGuardia 212-478-9782

(3) Newark 201-643-8347

(4) Kennedy 212-656-5373

(5) Washington National 703-684-8229

f. The abbreviated flight plans referred to in paragraphs 7b and 7d, above, are solely for the purpose of satisfying the requirements of FAR 93.125(b). Pilots wishing to file full flight plans for search and rescue purposes should do so in the normal manner through normal channels.

Francis J. Howland (signature)
for William M. Flener, Director
Air Traffic Service

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 375-284

APPENDIX B

MESSAGES TO AND FROM KANSAS CITY COMPUTER DEALING DIRECTLY WITH AFCP - EXAMPLES FOR JFK -

Reference: MITRE Technical Report, MTR-4109, Volume 6.

MESSAGES PRIOR TO INITIATING AFCP

1. Flow Control Capacities (from ZNY)

FCAP JFK 30 050200 052300

35 052300 060200

20 060200 060400

2. Flow Control Capacity Verification (to ZNY)

FCAP JFK IS 30 FROM 050200 to 052300

35 FROM 052300 to 060200

20 FROM 060200 to 060400

3. Request for Demand List (from ZNY)

REQ DEMAND JFK 050900 051200

4. Demand List (to ZNY)

JFK DEMAND

TIME	CAP	ARRIVAL	DEPARTURE	SURPLUS	MAX DELAY
050900	30	29	28	0	00+00
051000	30	35	29	5	00+40
051100	30	35	30	10	01+20
051200	30	34	29	½4	01+45

5. Request for Detailed Demand List (from ZNY)

REQ ARDEM JFK 050900 051200

6. <u>Detailed Demand List</u> (to ZNY)

JFK DETAILED ARRIVAL DEMAND LIST 050900 TO 051200

	0900	1000	1100	1200
ZNY	6	7	8	7
ZBW	4	3	4	4
ZBW				
ZBW				
ZBW				
ZID	2	1	1	1
YUL	6	6	7	6
YYZ	5	6	5	5
TOT	29	35	35	34
CAP	30	30	30	30
DLY	+00	+40	1+20	1+45

MESSAGES INITIATING AFCP

7. <u>Flow Control Alert</u> (to NY Center)

   JFK DELAY EXCEEDS 60 MINUTES.

   RECOMMEND AFCP AT 051100

8. <u>Initiate AFCP Message (from ZNY)</u>

   BEGIN AFCP JFK 051100

9. <u>Acknowledgement of Initiate AFCP Message (to ZNY)</u>

   ACK BEGIN AFCP JFK 051100

10. <u>AFCD Alert (to All Centers)</u>

    AFCP FOR JFK BEGINS 051100

MESSAGES AFTER AFCP BEGINS

11. Flow Control Allocations (to Zone 1 Centers)

FLOW CONTROL ALLOCATION TO JFK FOR AIRCRAFT SCHEDULED TO ARRIVE BETWEEN 050900 AND 051200

	0900	1000	1100	1200
ZNY	3	3	4	2
ZBW	4	4	3	3
ZDC	1	0	1	2
ZID	1	0	1	0
YUL	0	1	0	1
YYZ	1	0	1	1

MAXIMUM GROUND DELAY

+00	+00	+20	+45

12. Flow Control Allocations (to Zone 4 Centers)

FLOW CONTROL ALLOCATION TO JFK FOR AIRCRAFT SCHEDULE D TO ARRIVE BETWEEN 050900 AND 051200.

	0900	1000	1100	1200
ZNY	3	1	0	3
ABN	2	1	2	2
ZBN	1	1	0	1

MAXIMUM ENROUTE DELAY

0+00	0+40	1+20	1+45

13. Request for Allocation List (from Any Center

REQ ALLOC JFK ZMA 051200 051400

14. Center Allocation List (to Requesting Center)

FLOW CONTROL ALLOCATION TO ZMA FOR AIRCRAFT SCHEDULED TO ARRIVE BETWEEN 051200 AND 051400.

	1200	1300	1400
ZMA	0	0	0
		MAXIMUM GROUND DELAY	
	+40	1+45	2+45

15. Request for Flow Control Summary (from ZNY)

REQ FSUM JFK 050900 051200

16. Flow Control Summary (to ZNY)

FLOW CONTROL SUMMARY FOR JFK FROM 050900 TO 051200

AFCP BEGIN AT 051100

TIME	CAP	DEMAND	USED	MAX DELAY	GRD DELAY
050900	30	29	29	0+00	0+00
051000	30	35	30	0+40	0+00
051100	30	35	30	1+20	0+20
051200	30	34	30	1+45	1+20

17. Terminate AFCP Message (from ZNY)

END AFCP JFK 051800.

18. Acknowledgement of Terminate AFCP Message (to ZNY)

ACK END AFCP JFK 051800.

19. AFCP Alert (to All Centers)

AFCP FOR JFK ENDS 051800.

MESSAGES CONTROLLING THE PROGRAM

20. Set Delay Time Threshold

    SET DLY TME 60

21. Set Default Capacity

    SET DCAP JFK 60 0100 2300

22. Set Time of Last Flow Control Allocation List

    SET LALLOL JFK 0900

23. Enable or Disable AFCP Warnings

    SET FCWARN JFK DISABLE

    SET FCWARN JFK ENABLE

24. Shutdown Flow Control ARO Programs

    SET DOWN

    SET DOWN R

    SET DOWN QUICK

APPENDIX C

ASSUMPTIONS MADE IN CALCULATING
THE EFFECTIVENESS MEASURES
FROM THE FEBRUARY 5 DATA

PART A

Assumptions (a) through (j) given here were made in calculating the effectiveness measures of Table 9 and in obtaining Figures 14 through 20.

(a) It was assumed that substantially all flights to JFK or LGA on the day of interest were contained in the flight strip data, or in the OAG, or both. Thus, helicopter flights, local tower-to-tower flights, and non-scheduled flights for which flight strips are missing were neglected.

(b) The PTD and PTA of the OAG, where available, were used. When not available, the PTD of the flight strip data was used and PTA was calculated to be that PTD plus the actual time enroute. The flight strip PTA's were not used because they usually represented the latest PTA before landing clearance, rather than the original PTA that AFCP would use.

(c) The ETE of the OAG, where available, was used. Where not available, the ETE was taken to be equal to the actual time enroute, TENR*, as obtained from the flight strip data by the process described in (g) below.

(d) If a flight listed as an air file on the flight strips was contained in the OAG, then the actual time of departure, TD, was taken to be the PTD of the OAG, if it was not contained in the OAG, the actual and planned departure times were both taken to be the time of air filing. For JFK, there were 51 flights of the former, and 21 of the latter category; for LGA the figures were 0 and 2.

(e) A uniform 7 minutes was added to all flight strip landing times (columns 43 to 48 of the NAFEC cards) to obtain TA, the actual arrival times.

(f) The available arrival time TA* was obtained by adding to the time at the New York ARTCC entry fix (columns 30 to 32 of the NAFEC flight strip data) the minimum time required to go from the fix to landing, as obtained in PART C below, plus 7 minutes from landing to gate. The fix-to-gate times that were used are shown in Table 15.

(g) The actual time enroute TENR* was taken in all cases to be TA* minus the time of departure, TD. The TD was taken from the flight strips, except for air files as explained in (d).

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* See footnote on page 24

(h) The New York air delay was calculated as TA minus TA;* the ground delay was calculated as TD minus PTD. Aircraft that diverted, but did not return before 060500Z were given a TA of 060500Z.

(j) The landing capacity was taken to be equal to the actual landing rate during hours when 4 or more aircraft had arrived* but not landed; it was interpolated on a straight-line basis between those hours. The landing capacities thus derived are tabulated in Table 16. The usable capacity was calculated from the actual landing capacity and the schedule, as described in the section MEASURES OF EFFECTIVENESS.

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* See footnote on page 24

TABLE 15

MINIMUM TIMES FROM ENTRY FIX TO ARRIVAL GATE

ENTRY FIX	TIME TO JFK ARRIVAL(1)	TIME TO LGA ARRIVAL
PHL	25	-
SIE	27	-
7LE	36	-
ENO	30	29
ACY	21	-
7SB	34	-
MAD	23	23
7XG	20	-
HNK	28	27
IGN	23	-
XTU	31	-
SBY	34	32
7OB	31	-
P3E	28	-
9EP	30	-
RVH	21	-
7QM	20	-
7XL	35	-
SBM	34	-
7IK	23	-
7IB	24	-
7EP	32	31
7WE	35	-
9QR	37	-
SAX	21	-
HTO	24	-
SFK	35	35
9WA	21	21
7PP	21	-
ARD	23	-
PWL	24	23
RBV	21	21
9EM	21	-
EWT	29	23
OOD	26	24
AVP	27	26
7SM	25	-
9RO	-	25

(1) Add 10 minutes for flights landing between 1830Z and 2700Z, because runway 22 was in use at that time and a downwind leg over Long Island was required for most flights.

TABLE 15 (cont.)

ENTRY FIX	TIME TO JFK ARRIVAL	TIME TO LGA ARRIVAL
MIP	-	30
7EL	-	31
PSB	-	35
7QN	-	22
IPT	-	31
CMK	-	20
HAR	-	30
HPN	-	19
ISP	-	20
7RE	-	35
7YJ	-	23

TABLE 16 ARRIVAL CAPACITIES DERIVED FROM FEBRUARY 5 DATA

	JFK			LGA		
START OF HOUR (GMT)	NUMBER ARRIVED IN HOUR (1)	PEAK WAITING IN HOUR (2)	EX POST FACTO ARRIVAL CAPACITY (3)	NUMBER ARRIVED IN HOUR (1)	PEAK WAITING IN HOUR (2)	EX POST FACTO ARRIVAL CAPACITY (3)
0500	14	7	14	5	3	(24)
0600	8	3	(13)	5	2	(24)
0700	11	2	(13)	0	0	(24)
800	5	2	(13)	0	1	(24)
900	8	3	(13)	0	0	(24)
1000	2	1	(13)	0	0	(24)
1100	1	0	(13)	0	0	(24)
1200	4	3	(13)	2	3	(24)
1300	12	5	12	7	3	(24)
1400	11	4	11	24	7	24
1500	11	6	11	13	3	(23)
1600	10	4	10	22	8	22
1700	22	4	22	24	7	24
1800	11	3	(12)	15	3	(23)
1900	1	12	1	27	3	(27)
2000	6	14	6	21	8	21
2100	0	28	0	25	9	25
2200	19	34	19	11	14	11
2300	30	30	30	31	9	31
0000	28	27	28	23	7	23
0100	29	35	29	14	13	14
0200	31	36	31	31	15	31
0300	26	30	26	7	3	(30)
0400	30	24	30	10	0	(30)

NOTES (1) ACTUAL ARRIVALS WITHIN THE HOUR, BASED ON FLIGHT STRIP DATA.

(2) AVAILABLE ARRIVALS* LESS DIVERSIONS PLUS RETURNEES, WITHIN THE HOUR.

(3) THE ACTUAL NUMBER LANDED IN THE HOUR FOR HOURS IN WHICH THE PEAK NUMBER WAITING IS 4 OR MORE, AND AN INTERPOLATED VALUE OTHERWISE; BUT NOT LESS THAN THE ACTUAL. THE INTERPOLATED VALUES ARE IN PARENTHESES.

* See footnote on page .

PART B

In addition to assumptions (a) through (j), the following six assumptions were made in obtaining the results of Table 9, covering the effectiveness measures for February 5 under modified conditions:

(k) The departure delay of each flight was taken to be the same as given in the data, even though it may have been the result of AFCP on the 5th, unless that flight was selected for ground hold under the modified conditions. In that case, the exact ground hold was assumed. This was done because of the difficulty of extracting the actual AFCP ground holds from the February 5 data. (Note that the effect of ground delays and enroute delays is investigated in the simulation study described in the fifth section of this report.

(l) It was assumed that individual flights were controlled under AFCP and that new allocations were issued every hour. This was done to obtain a sharper comparison between cases, some of which involve only one or two hours of control.

(m) The same enroute delays as occurred in the February 5 data would obtain for both controlled and uncontrolled flights.

(n) Diverted flights were counted as air holds until the flight could be accommodated or until 0500Z on February 6, whichever occurred first.

(o) Flights were not considered for AFCP control if their ETE was not at least one hour less than the notification time, which was assumed to be the same for all flights.

(p) Cancellations in any given arrival hour were assumed to be known to the AFCP control prior to notification of allocations for that hour. This assumption meant that the scheduled cumulative arrivals were those shown in Figures 14 and 15, labelled "Available, without Diversions".

PART C

The flight time from entry fix to landing excluding delays is needed to determine the air delay at ZNY, since the landing times obtained from the flight strip data include air delays. This direct or "no-delay" travel time depends on many factors, the principal ones being (1) the location of the fix relative to the landing point, (2) the approach path selected, (3) the aircraft descent profile, (4) the altitude at the entry fix, and (5) winds. This analysis takes account only of the first of these influences, and to a lesser extent, of the second. In brief, a relation is obtained between the travel time and the direct distance from fix to landing. The times are then adjusted for long approaches.

If the fix-to-landing times from the flight strips are plotted, vs. straight line distance from fix to landing, a very large scatter is obtained because of air delays. If only the minimum times for each fix are employed, the results will not be representative of most flights. Hence the following compromise was devised: All fixes with 20 or more flights were selected, and for each of these fixes the average of the shortest 10% of the travel times was plotted vs. distance to landing. The results are shown in Figure C-1. The straight line shown in the figure is within about 8 minutes of the times for all the selected fixes, and within about 5 minutes for 10 of them. This straight line was used to obtain the minimum fix-to-arrival times of Table 15 simply by reading off for each fix the ordinate corresponding to the abscissa (direct-line distance to JFK or LGA).

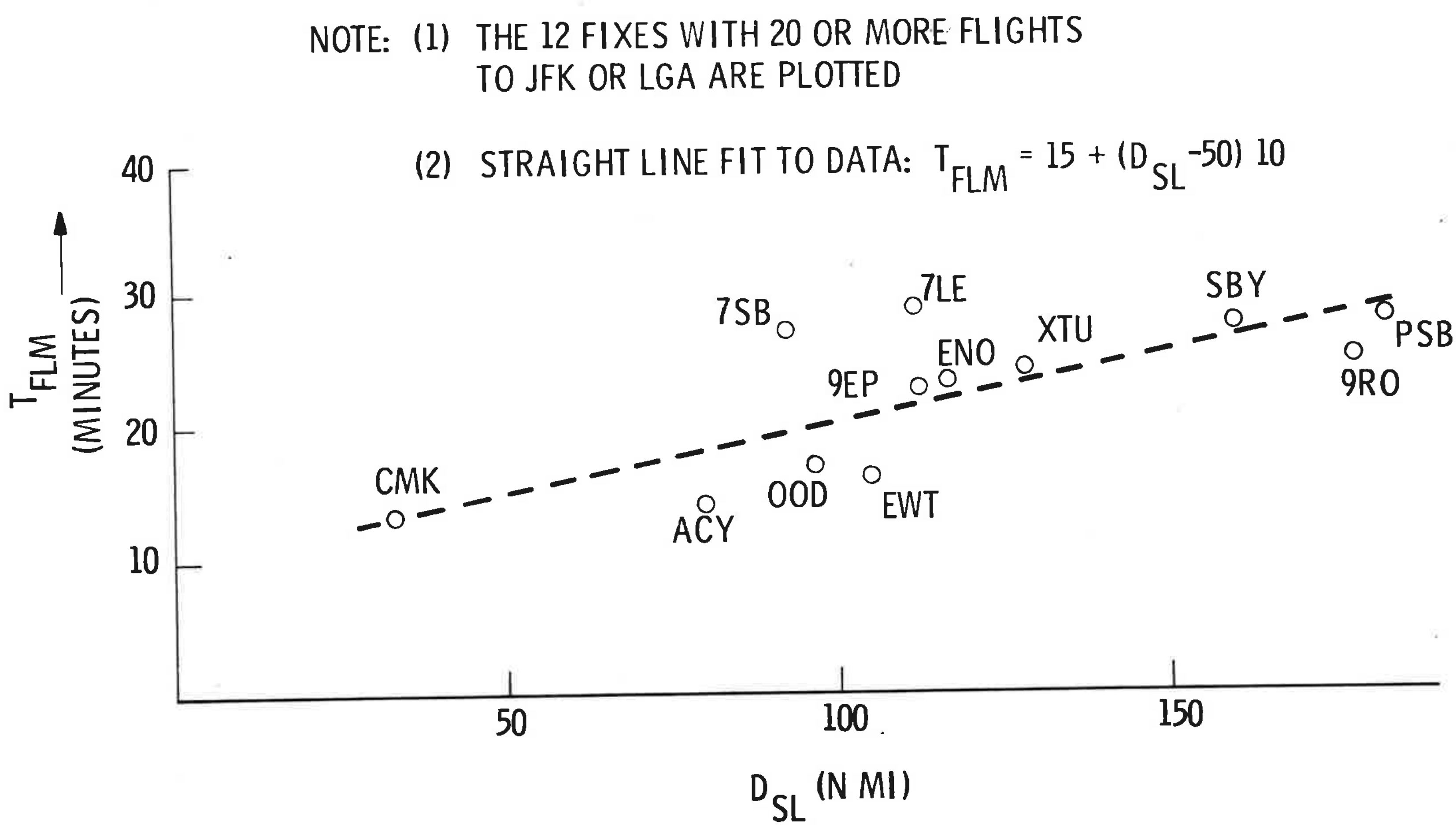

Figure C-1. Minimum Time T_{FLM} From Fix to Landing vs. Straight-Line Distance D_{SL} From Fix to Landing