Proceedings of the 1983
Winter Simulation Conference
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THE AIRCRAFT MOVEMENT SIMULATION MODEL

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The following paragraphs describe a computer program for simulating the movements of aircraft on the apron, taxiways, and runways of an airport. The purpose of this program is to enable the airport planner to evaluate the performance of a given airport layout from an operational point of view. Likewise, he can compare alternative layouts, investigate the impact of a change in airport activity (flight schedule), or assess the impact of an unusual situation (closing of a runway). The inherent assumptions of the model are discussed, and the various output reports and graphics are illustrated and explained.

1. PROGRAM DESCRIPTION

The simulation program called AIRMOV is a graphic interactive program. It is graphic because the output appears on a video screen as a schematic of the airport layout together with scaled symbols of aircraft moving on the runways, taxiways, and apron. It is interactive because the operator can interfere with the normal unfolding of the simulation, which follows the schedule of aircraft movements provided in the input. Depending on the situation shown on the screen, the operator can take one of several actions. He can hold an aircraft (for an indefinite time), delay an aircraft (fixed number of time steps), release an aircraft previously held, reroute an aircraft, or queue an aircraft for departure.

The program handles three types of movements: arrivals, departures, and ground movements. For arrivals, the program starts counting the movement time from the instant an aircraft appears over the threshold until it stops at the gate (blocks on). If the aircraft was delayed in the air (stacking), the airborne delay is added to the movement time. For departures, the movement time starts when the plane leaves the gate (blocks off) until it is airborne and has cleared the runway end. The ground movement is an aircraft moving under its own power (or being towed) between two locations at the airport. Typically, such a movement would be between two gates, between a gate and the maintenance area, or to and from an overnight parking area.

The program automatically ensures the separation of aircraft on the runway according to ATC practice. These rules can be either IFR or VFR and are specified in the input data. Likewise, aircraft taxiing across an active runway are also handled automatically. If necessary, the program can handle intersection takeoffs and taxiing along an active runway.

The main function of the program is to keep all aircraft moving along their assigned routes in time steps of 0.1 minute (6 seconds). At each time step, the program will check whether any conflicts between two or more aircraft have occurred. A conflict is defined as the inner occupancy rectangle of an aircraft penetrating the outer rectangle of another aircraft (Figure 1).

When a conflict occurs, the word CONFLICT and an arrow pointing to the aircraft involved will appear. The simulation stops and the operator moves back in time, one or more steps, to a time prior to the conflict. He will then solve the conflict by holding, delaying, or rerouting one of the aircraft. The simulation will then proceed normally if the conflict has been successfully solved. If the operator's action was not appropriate, the conflict will recur and the operator will have to start the conflict solving cycle again. An example of a conflict solving action is shown in Figure 2.

The consequences of all the operator's actions are logged by the program in a file. For each

CH1953-9/83/0000-0641 $01.00

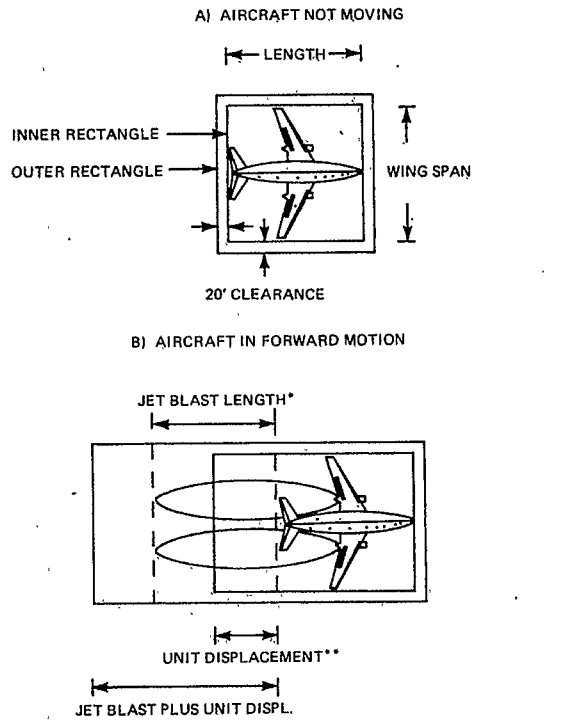

Figure 1. Aircraft Occupancy Areas

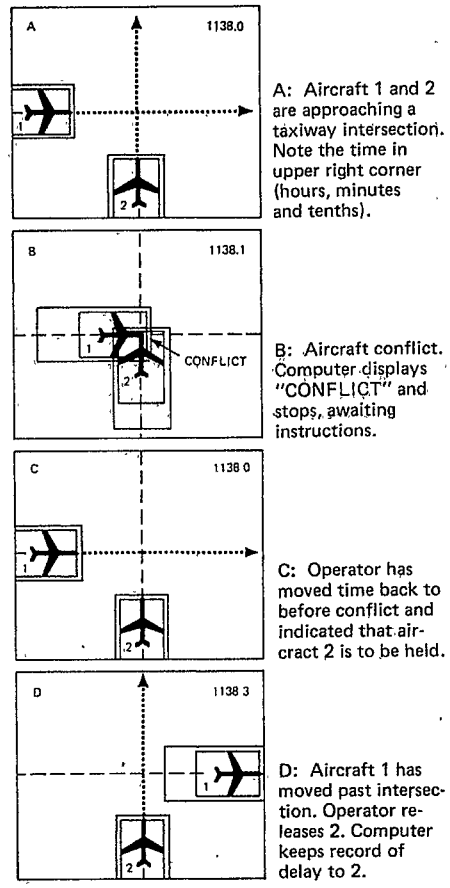

Figure 2. Handling of a Conflict

movement, the program will keep track of the actual route followed and the actual time it took to complete the movement. The actual movement time is further broken down into a taxiing time, an apron/taxiway delay time, and a runway delay time.

The location of delays occurring on the airport is stored by the program and can be displayed graphically as a small "x" on the airport layout.

The program has a special feature which allows the operator to cordon off certain areas of the airport. The cordon is defined as a segment between two points. The program will keep track of all the aircraft going through this segment, noting the time at which an aircraft cuts into the segment and the time at which it clears it. These cordons can be positioned across runways, taxiways, or portions of the apron.

2. INTRINSIC ASSUMPTIONS

The airport layout is described by a series of up to 400 points given by their x, y coordinates. The routes followed by every aircraft are made up of a number of straight lines connecting points that are part of the airport layout. Between each pair of points along its route, an aircraft will move at a constant speed that depends on the aircraft location. The program stores different speeds for gate maneuvers, movement on the apron, on different taxiways, and on runways while taking off or landing. Furthermore, since the simulation proceeds in fixed steps of 0.1 minute, the time an aircraft takes to go between two points of its route will always be rounded off to an entire number of time steps. This may result in the movement time being off by plus or minus one time step from its exact calculated value.

The model can handle traffic on up to nine runways. Separation of aircraft on the runways is assured by two mechanisms: the occupancy times and the separation times. The former procedure will block one or more runways whenever an aircraft is on an active runway, whether it is landing, taking off, or taxiing across it. The runways blocked will always include the one on which the aircraft is moving. In addition, for takeoffs and landings, the occupancy time mechanism will also block intersecting runways or parallel runways that are less than 4,300 feet from the runway used, if the run is made for IFR conditions. The runways blocked will be freed when the aircraft clears the runway it is using or, for intersecting runways, when the aircraft has passed the intersection point.

The separation time mechanism provides a minimum separation time between two aircraft. Depending

on the category of each aircraft (small, large, heavy), the runway used by each aircraft, and whether these aircraft are landing or taking off, the program will be directed to the appropriate separation time.

The actual separations between consecutive aircraft in the model are then taken as the larger of the occupancy time or the separation time.

The program can also store the dimensions and category of up to 25 different aircraft types. The dimensions are the length, the wingspan, and the jet blast length (50 mph contour for breakaway thrust). The three possible categories are:

- Category 1: small planes, 12,500 pounds maximum gross takeoff weight or less
- Category 2: large planes, 12,500 to 300,00 pounds maximum gross takeoff weight
- Category 3: heavy planes, 300,000 pounds maximum gross takeoff weight and over

Lastly, a distance of 20 feet is added to an aircraft's wingspan and length to form its outer rectangle of occupancy. This ensures a minimum physical separation of 20 feet between aircraft.

3. OUTPUT REPORTS

Five reports are available to the user. Two of them can be obtained at any time during the simulation; the other three require that the simulation be completed.

The former reports are the "Summary of Delay Statistics" and the "Cordon Crossing Summary." The latter three are the "Movement Analysis," the "Listing of Cordon Crossings," and the "Log of Operator's Actions" reports. All reports are described in the following subsections.

3.1 Summary of Delay Statistics

This report is shown in Figure 3. Its purpose is to show movement statistics by hour. Only movements that are completed at the time the report is made are included. Also, they are summarized in the hour during which they are started.

The movements are further broken down into two groups: commercial and noncommercial traffic (general aviation, military flights, corporate flights, or training). Movements of commercial traffic are summarized by ten columns of statistics. These are, from left to right and for each hour of simulation:

- Number of commercial movements (arrivals, departures, and ground-to-ground movements)
- Total aircraft-minutes accumulated by these movements (includes taxiing time, apron and taxiway delays, and runway delays)
- Number of arriving movements (landings)
- Number of arriving movements that were delayed in the air because the runway was not immediately available
- Total aircraft-minutes of airborne delays
- Number of departing movements (takeoffs)
- Number of departing movements that were delayed because of a queue at the runway
- Total aircraft-minutes lost while queuing for takeoff
- Number of aircraft movements that were delayed while taxiing on the apron or the taxiways
- Total aircraft-minutes of delay due to apron/taxiway conflicts

Only three columns of statistics are given for noncommercial traffic:

- Total number of movements

SUMMARY STATISTICS FOR APRON/TAXIWAY SIMULATION

JUN 23, 1981 16:02P.M.

	COMMERCIAL AVIATION										GENERAL AVIATION		
HOUR	NUMBER OF MVMTS	TOTAL GROUND TIME (MIN.)	NUMBER OF LANDGS	NUMBER OF ARR. RUNWAY DELAYS	ARR. RUNWAY DELAY (MIN.)	NUMBER OF TAK.OF	NUMBER OF DEP. RUNWAY DELAYS	DEP. RUNWAY DELAY (MIN.)	NUMBER OF TAXIING DELAYS	TOTAL TAXIING DELAY (MIN.)	NUMBER OF MVMTS	NUMBER OF RUNWAY DELAYS	TOTAL RUNWAY DELAY (MIN.)
0000-0059	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0100-0159	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0200-0259	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0300-0359	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0400-0459	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0500-0559	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0600-0659	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0700-0759	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0800-0859	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
0900-0959	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1000-1059	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1100-1159	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1200-1259	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1300-1359	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1400-1459	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1500-1559	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1600-1659	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1700-1759	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
1800-1859	41	284.3	26	17	35.6	15	5	3.0	12	6.7	9	2	2.4
1900-1959	94	992.0	57	52	391.2	37	21	25.2	22	15.0	22	18	91.4
2000-2059	27	191.5	12	8	33.5	15	6	5.6	6	3.3	5	5	54.1
2100-2159	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
2200-2259	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
2300-2359	0	.0	0	0	.0	0	0	.0	0	.0	0	0	.0
TOTAL	162	1467.8	95	77	460.3	67	32	33.8	40	25.0	36	25	147.9

Figure 3. Sample of a "Summary of Delay Statistics" Report

- Number of movements that were delayed on the runways (arrivals and departures)
- Total aircraft-minutes lost by runway delays

3.2 Cordon Crossing Summary

Figure 4 shows a sample of this report for four cordons. In this example, these cordons are located across each active runway, just after the threshold, and are used to count the aircraft landing and taking-off on each runway. These cordons can also be used to count the traffic on specific taxiways and/or certain parts of the apron. The original use of these cordons was to represent sections of the Ground Support Equipment routes on the apron or across taxiways and to monitor the number of aircraft crossing them each hour as well as to total the number of minutes each cordon was interrupted during each hour. With these data, the user can estimate the number of vehicle-minutes of delay to the GSE traffic and can use this information to select one among several alternatives of GSE route layout. For each cordon and for each hour of the simulation, the cordon crossing summary report gives the number of aircraft crossing the cordon (second line) and the number of minutes the cordon is interrupted during the hour (first line).

3.3 Movement Analysis Report

Each line of this report, shown in Figure 5, gives ten columns of statistics for each user-defined group of movements. Such a group of movements can be defined as all the movements whose origins and destinations belong to user-specified sets.

For example, all arrivals from one runway going to a group of gates on the apron could form such a set. This report can also be run so that each line represents only one movement.

The following statistics are available for each movement or group of movements:

- Total movements
- Number of movements incurring a runway delay (arrival or departure); minutes of delay per aircraft delayed; minutes of delay per movement
- Number of movements delayed because of an apron/taxiway delay; minutes of delay per aircraft delayed; minutes of delay per movement
- Average taxiing distance
- Average taxiing time (time during which the aircraft is moving)
- Average movement time (total time, including delays, needed to complete the movements)

In the last three items, time and distance include the full length of the runway for departures. For arrivals, they include the runway from the threshold to the exit used.

The taxiing time and distance in these statistics may differ from those computed from each preassigned movement route because during the simulation, certain conflicts are solved by rerouting a movement. Also, when an aircraft is queuing for departure, it will move at a slow speed whenever the queue moves up one position.

CORDON INTERFERENCE SUMMARY

TOTAL MINUTES BLOCKED
NUMBER OF BLOCKAGES

HOUR	CORDON NUMBER 1	2	3	4
0000-0059	.0	.0	.0	.0
	0	0	0	0
0100-0159	.0	.0	.0	.0
	0	0	0	0
0200-0259	.0	.0	.0	.0
	0	0	0	0
0300-0359	.0	.0	.0	.0
	0	0	0	0
0400-0459	.0	.0	.0	.0
	0	0	0	0
0500-0559	.0	.0	.0	.0
	0	0	0	0
0600-0659	.0	.0	.0	.0
	0	0	0	0
0700-0759	.0	.0	.0	.0
	0	0	0	0
0800-0859	.0	.0	.0	.0
	0	0	0	0
0900-0959	.0	.0	.0	.0
	0	0	0	0
1000-1059	.0	.0	.0	.0
	0	0	0	0
1100-1159	.0	.0	.0	.0
	0	0	0	0
1200-1259	.0	.0	.0	.0
	0	0	0	0
1300-1359	.0	.0	.0	.0
	0	0	0	0
1400-1459	.0	.0	.0	.0
	0	0	0	0
1500-1559	.0	.0	.0	.0
	0	0	0	0
1600-1659	.0	.0	.0	.0
	0	0	0	0
1700-1759	.0	.0	.0	.0
	0	0	0	0
1800-1859	1.7	.8	1.5	.5
	17	8	15	3
1900-1959	4.4	2.4	3.2	3.3
	44	24	32	18
2000-2059	2.2	.6	1.6	1.8
	22	6	16	5
TOTAL	8.3	3.8	6.3	4.8
	83	38	63	26

Figure 4. Cordon Crossing Summary

MOVEMENT ANALYSIS

DATE: JUN 24, 1981
TIME: 12:53P.M.

ALL MOVEMENTS START BETWEEN 1830 AND 2030

ORIG.	DEST.	MVNTS	RUNWAY DELAYS(MIN) ACM	PER CON	PER MVT	TAXIING DELAYS(MIN) ACM	PER CON	PER MVT	TAXI DIST (FEET)	TAXI TIME (MIN)	GROUND TIME (MIN)
EAST	28R	18	10	1.24	.69	6	.70	.23	15567.	4.5	5.4
SOUTH	28R	4	3	.63	.47	2	.35	.17	18602.	7.2	7.8
WEST	28R	3	2	1.85	1.23	1	.10	.03	19437.	6.8	8.1
NORTH	28R	11	7	1.33	.85	2	.60	.11	14742.	5.1	6.1
EAST	28C	10	3	.67	.20	2	.70	.14	21965.	6.9	7.2
SOUTH	28C	10	4	.60	.24	2	.65	.13	21927.	8.2	8.6
WEST	28C	8	2	.50	.12	4	.57	.29	25281.	9.3	9.7
NORTH	28C	3	1	1.10	.37	1	.20	.07	25661.	8.4	8.9
EAST	ALL	28	13	1.11	.51	8	.70	.20	17852.	5.4	6.1
SOUTH	ALL	14	7	.61	.31	4	.50	.14	20977.	7.9	8.4
WEST	ALL	11	4	1.17	.43	5	.48	.22	23687.	8.6	9.3
NORTH	ALL	14	8	1.30	.74	3	.47	.10	17082.	5.8	6.7
ALL	28R	47	29	1.21	.74	14	.49	.15	15951.	4.6	5.5
ALL	28C	37	13	.73	.26	11	.54	.16	22235.	7.4	7.8
28R	EAST	15	10	1.03	.69	3	.53	.11	13806.	5.1	5.9
28R	SOUTH	3	1	.90	.30	0	.00	.00	14050.	5.4	5.7
28R	WEST	3	2	.65	.43	1	1.00	.33	11435.	4.1	4.9
28R	NORTH	6	3	.93	.47	2	1.50	.50	10933.	3.9	4.8
28L	EAST	16	15	10.19	9.56	6	.52	.19	14695.	5.6	15.4
28L	SOUTH	14	13	8.63	8.01	2	.40	.06	12185.	4.3	12.4
28L	WEST	8	8	6.02	6.02	1	.30	.04	15904.	5.6	11.7
28L	NORTH	10	7	8.86	6.20	3	.30	.09	19604.	8.9	13.2
32	EAST	3	3	2.83	2.83	0	.00	.00	15481.	5.8	8.6
32	SOUTH	1	1	1.50	1.50	0	.00	.00	18294.	6.4	7.9
32	WEST	6	6	4.52	4.52	2	1.45	.48	18576.	6.6	11.6
32	NORTH	10	8	4.07	3.26	0	.00	.00	15673.	5.5	8.8
ALL	EAST	34	28	6.13	5.05	9	.52	.14	14372.	5.4	10.6
ALL	SOUTH	18	15	7.64	6.37	2	.40	.04	12835.	4.6	11.0
ALL	WEST	17	16	4.79	4.51	4	1.05	.25	16058.	5.7	10.5
ALL	NORTH	26	18	5.41	3.75	5	.78	.15	16091.	5.7	9.6
28R	ALL	33	18	.94	.51	6	.93	.17	13399.	4.8	5.5
28L	ALL	57	52	9.62	8.78	13	.40	.09	14136.	5.1	14.0
32	ALL	24	22	3.64	3.34	3	1.23	.15	15500.	5.3	8.8
ALL	ALL	198	134	4.79	3.24	47	.58	.14	16123.	5.4	8.8

Figure 5. Movement Analysis

3.4 Cordon Crossing Listing Report

For each cordon defined by the user, this report will give a chronological list of all aircraft crossing the cordon. A sample of this report is shown in Figure 6; two lines of data are shown for each aircraft. The first gives the time at which the aircraft starts going through the cordon, the cordon ID, the cordon status (closed), the movement ID, the start time of the movement, the movement class, and the aircraft type. The second line contains only the time the aircraft cleared the cordon and the cordon status (open). Placing such a cordon across a runway allows the user to check the usage of the runway and the separation by aircraft type.

3.5 Log of Operator's Actions

This report is a log of all the actions taken by the operator during the simulation (Figure 7). This log shows four types of actions and a queue status report. These actions and their related statistics are:

- DELAY, action time, movement ID, number of cycles, and x, y coordinates of aircraft positions
- QUEUE, action time, movement ID
- HOLD, action time, movement ID, aircraft position
- RELEASE, action time, movement ID

The queue status report is given automatically after each QUEUE and RELEASE command. The first command is given when an aircraft joins a queue of departing aircraft at the runway and the second command occurs when the aircraft leaves the queue and gets ready to taxi into position for takeoff.

The first line of the queue status report specifies the report time, the point defining the head of the queue, the queue number, the movement ID involved, the runway ID, and the queue length. The second line lists the movement IDs of all aircraft in the queue.

4. GRAPHIC OUTPUT

This output represents snapshots of different situations and/or conflicts occurring during the simulation. Since the graphic terminal used in this simulation is a storage scope, the user can also obtain a time exposure over a number of time cycles. Such an exposure shows the position of each aircraft every six seconds on the airport layout (Figure 8). The operator can also enlarge any part of the airport to look more closely at a particular situation (Figure 9). In all these outputs, the simulation time is shown on the upper right corner of the screen. Also listed at the top of the screen is the movement ID of all the aircraft active at the simulation time. Some movement IDs are followed by an "A", for active, which indicates that the movement is shown on the screen. The other movement IDs are aircraft that are still airborne (delayed arrival).

```
LISTING OF CORDON INTERFERENCES

1832.1   1 CLOSED     4  1832GA   BE9
1832.2   1 OPEN       0     0
1836.1   1 CLOSED     7  1836DA   D9S
1836.2   1 OPEN       0     0
1837.5   1 CLOSED     8  1836DA   DHT
1837.6   1 OPEN       0     0
1840.2   1 CLOSED    10  1838GD   SWM
1840.3   1 OPEN       0     0
1840.7   1 CLOSED    13  1840DA   298
1840.8   1 OPEN       0     0
1843.1   1 CLOSED    16  1843GA   PAN
1843.2   1 OPEN       0     0
1846.2   1 CLOSED    18  1843DD   PRP
1846.3   1 OPEN       0     0
1847.1   1 CLOSED    24  1847DA   727
1847.2   1 OPEN       0     0
1848.4   1 CLOSED    21  1845DD   298
1848.5   1 OPEN       0     0
1849.1   1 CLOSED    28  1849GA   PAF
1849.2   1 OPEN       0     0
1849.9   1 CLOSED    20  1845DD   SH3
1850.0   1 OPEN       0     0
1851.2   1 CLOSED    26  1847DD   D9S
1851.3   1 OPEN       0     0
1853.1   1 CLOSED    38  1853DA   D9S
1853.2   1 OPEN       0     0
1854.2   1 CLOSED    33  1852GD   DHT
1854.3   1 OPEN       0     0
1854.7   1 CLOSED    39  1853DA   747
1854.8   1 OPEN       0     0
1857.7   1 CLOSED    46  1856DA   BE9
1857.8   1 OPEN       0     0
1859.2   1 CLOSED    49  1859GA   CN5
1859.3   1 OPEN       0     0
1900.1   1 CLOSED    42  1855DD   727
1900.2   1 OPEN       0     0
1900.8   1 CLOSED    47  1856DD   DHT
1900.9   1 OPEN       0     0
```

Figure 6. Cordon Crossing Listing

```
1857.3 DELAY  47   5 CYCLES AT (   910,  -300)
1858.6 DELAY  41   2 CYCLES AT (  1802,  1450)
1858.8 DELAY  47   2 CYCLES AT (  1600,  1214)
1859.2 DELAY  46   1 CYCLES AT (  1356,  1750)
1859.7 QUEUE  47
1859.7 QUEUE STATUS AT POINT 119 QUEUE   5MVT B  47 RUNWAY   1 LENGTH OF QUEUE   1
MVT IN QUEUE  47   0   0   0   0   0   0   0   0   0
1859.8 HOLD  47 AT (  3040,  1750)
1859.9 RELEASE  47
1859.9 QUEUE STATUS AT POINT 119 QUEUE   5MVT B  47 RUNWAY   1 LENGTH OF QUEUE   0
MVT IN QUEUE   0   0   0   0   0   0   0   0   0   0
1901.5 DELAY  51   5 CYCLES AT (  3650,  1450)
1902.5 DELAY  56   1 CYCLES AT (  4600, -1592)
1905.4 DELAY  45   6 CYCLES AT (  1206,   400)
1906.2 DELAY  59   1 CYCLES AT (   300,  1750)
1906.6 DELAY  59  14 CYCLES AT (   300,  1142)
1907.0 DELAY  57   6 CYCLES AT (  5988,  -570)
1908.0 DELAY  59   5 CYCLES AT (   300,  1142)
1912.7 DELAY  69  13 CYCLES AT ( -1403,  -400)
1913.0 DELAY  69  -2 CYCLES AT ( -1403,  -400)
1914.9 DELAY  70   3 CYCLES AT (  -520, -1450)
1916.6 DELAY  76   2 CYCLES AT (  1900,  1750)
1917.0 DELAY  70   5 CYCLES AT (  3797, -1750)
1922.2 DELAY  81  18 CYCLES AT ( -1092,   200)
1924.0 DELAY  81   3 CYCLES AT ( -1092,   200)
1924.0 DELAY  81   2 CYCLES AT ( -1092,   200)
1924.5 DELAY  81   2 CYCLES AT ( -1092,   200)
1928.0 DELAY  79   6 CYCLES AT (  5050, -2450)
1928.7 QUEUE 106
1928.7 QUEUE STATUS AT POINT 119 QUEUE   5MVT M 106 RUNWAY   1 LENGTH OF QUEUE   1
MVT IN QUEUE 106   0   0   0   0   0   0   0   0   0
1928.7 HOLD 106 AT (  3250,  1450)
1928.7 DELAY  79   1 CYCLES AT (  5050, -2275)
1928.9 RELEASE 106
1928.9 QUEUE STATUS AT POINT 119 QUEUE   5MVT B 106 RUNWAY   1 LENGTH OF QUEUE   0
MVT IN QUEUE   0   0   0   0   0   0   0   0   0   0
1929.3 DELAY 104   1 CYCLES AT (  4339, -1750)
1930.5 DELAY 105   3 CYCLES AT (  1900,  1750)
1930.8 QUEUE 108
1930.8 QUEUE STATUS AT POINT 271 QUEUE   6MVT M 108 RUNWAY   2 LENGTH OF QUEUE   1
MVT IN QUEUE 108   0   0   0   0   0   0   0   0   0
```

Figure 7. Log of Operator's Actions

The aircraft shown on the screen are represented by symbols scaled to the correct length and wingspan for each aircraft type. Two other modes of representation are available to the user: the movement IDs and the occupancy rectangles. In the enlargement (Figure 9), these three symbols are used for each aircraft.

On the full layout (Figure 8), the airport will, in general, appear distorted because the computer uses a different scale for the x and y coordinates in order to use the screen fully. On the enlargement, however, the view will always be undistorted.

Another graphic output available to the user is the delay map, shown in Figure 10. The "x"s shown on the airport layout each indicate the location where an aircraft was delayed. The exact location of the delay (center of aircraft) corresponds to the lower left corner of the x.

5. PROGRAM APPLICATIONS

This program is an inhouse developement of Bechtel Civil & Minerals, Inc. It is written in FORTRAN, runs on a UNIVAC 1182, and requires a storage scope as a terminal (Tektronix 4016).

It has been used on several major airport projects in the Middle East and in the U.S. For new airports, it is used to verify the apron/taxiway/runway design and integration. Several operating policies, traffic patterns, and levels of activity are simulated until the planner is confident that his design is flexible, has adequate capacity, and does not have any superfluous taxiways and apron areas.

For existing airports, the program is used to investigate capacity problems and to compare alternative solutions. These can range from restraints on the flight schedule, to changes in the operating policy, to additions of taxiways and/or apron pavement. The realism of the simulation program has been verified by an air traffic control supervisor of the FAA and by several airline officials.

Because of this realism, the program can also be used as a training tool for ground controllers of new airports where no previous experience exists. At existing airports, ground controllers can use the program to learn how to handle unusual and rare situations.

In summary, this simulation program, with its graphic display and its interactive features, gives the user an insight into the performance of an airport that goes beyond the quantitative data obtained through the available output reports. He can get a "feel" for the type of situations and problems that are likely to develop on a specific airport.

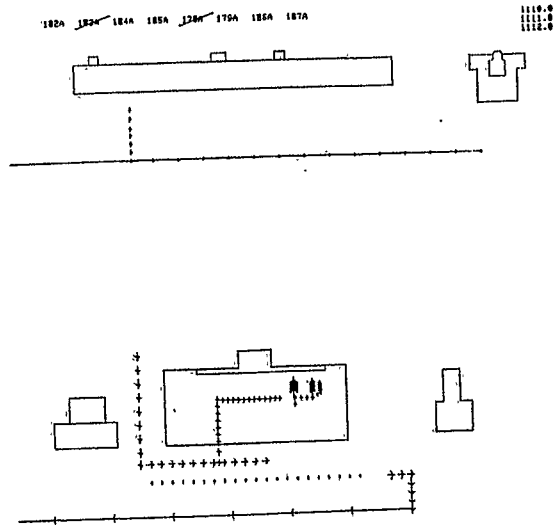

Figure 8. Full Layout Time Exposure

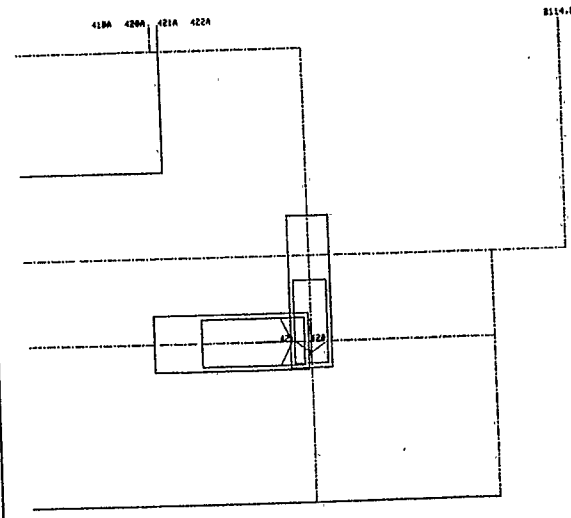

Figure 9. Enlargement of a Situation

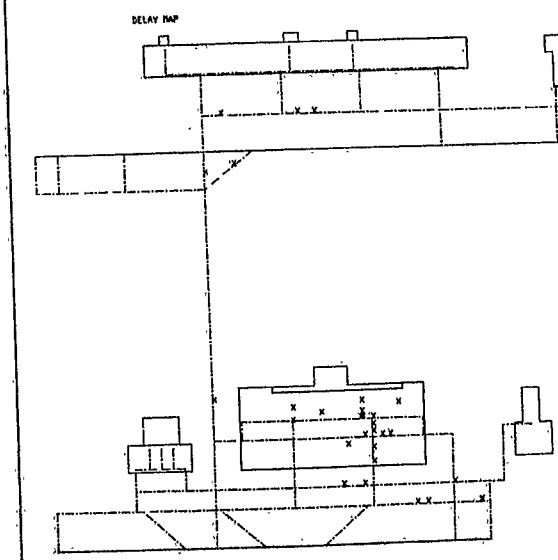

Figure 10. Delay Map