

CENTER FOR CONSTRUCTION ENGINEERING AND MANAGEMENT

SIMULATION AND VISUALIZATION OF AIR-SIDE OPERATIONS AT DETROIT METROPOLITAN AIRPORT

By

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ABSTRACT

In recent years, airline flight delays have been among the most troublesome problems in the national transportation system. Although bad weather has historically been the main cause of delays, a growing reason has been the inability of the nation's air transport system to efficiently absorb all of the aircraft trying to use limited airspace or trying to take off or land at busy airports. Simulation modeling and visualization can be of substantial help in the efficient design of airport operations, which in turn can mitigate some of the abovementioned capacity problems. This study presents the simulation model and 3D animation of the airside airport operations at Detroit Metro Airport, Romulus, Michigan. The simulation model is developed in STROBOSCOPE (Martinez 1996) and the 3D animation is created using VITASCOPE (Kamat 2003).

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TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 PROBLEM STATEMENT 1
1.2 RESEARCH SCOPE AND OBJECTIVE 2
1.2.1 Research Scope 2
1.2.2 Research Objective 3
2 PREVIOUS WORK ON AIRPORT OPERATIONS SIMULATION AND VISUALIZATION 5
3 OVERVIEW ON AIRPORTS PERFORMANCE 7
3.1 INTRODUCTION 7
3.2 RUNWAYS AND TAXIWAYS 8
3.3 AIRCRAFT MIX 9
3.4 METEREOLOGICAL CONDITIONS AND APPROACH PROCEDURES 10
4 ABOUT DETROIT METROPOLITAN WAYNE COUNTY AIRPORT 11
4.1 INTRODUCTION 11
4.2 AIRPORT LAYOUT 12
4.3 RUNWAY CONFIGURATION 13
5 SIMULATING RUNWAY OPERATIONS AT DTW 15
5.1 MODEL PARAMETERS AND ASSUMPTIONS 15
5.2 DIFFERENT AIRPORT OPERATIONS SCENARIOS 19
5.2.1 Scenario I - IFR Conditions 19
5.2.2 Scenario II - VFR Conditions (case I) 19
5.2.3 Scenario III - VFR Conditions (case II) 19
5.3 STROBOSCOPE SIMULATION MODELS 20
5.3.1 Introduction 20
5.3.2 Scenario I 21
5.3.2.1 Modeling Arrivals, Approach and Landing 21
5.3.2.2 Modeling Departures 26
5.3.3 Scenario II 29
5.3.3.1 Modeling Arrivals, Approach and Landing 29
5.3.3.2 Modeling Departures 31
5.3.4 Scenario III 32
5.3.4.1 Modeling Arrivals, Approach and Landing 32
5.3.4.2 Modeling Departures 32
6 VALIDATING DTW AIRPORT SIMULATION MODELS USING 3D ANIMATION . 34
6.1 INTRODUCTION: 3D ANIMATION AND OBJECTIVES 34
6.2 3D ANIMATION TOOL**:** VITASCOPE 34
6.2.1 VITASCOPE characteristics 34
6.2.2 Generating Vitascope Animation Commands 35
6.2.3 Developing CAD Models of Simulation Objects 36
6.3 VIZUALIZING DTW AIRPORT OPERATIONS USING VITASCOPE 37
6.3.1 PATH and NONDIRECPATH Animation Statements 37
6.3.2 TIME, CREATE, PLACE, MOVE and DESTROY Animation 37
6.3.3 CLASS, SET CLASS (RGP and AFTCLEARANCE) Animation STATEMENTS .. 39
6.3.4 Larger Portion of a Trace file 40

6.3.5 Animation Snapshots of Visualized Operations at DTW 41
7 DTW AIRPORT SIMULATION RESULTS 44
7.1 VARIABLES AND COLLECTORS 44
7.2 ASSUMPTIONS 44
7.3 RUNWAY PERFORMANCE 45
7.3.1 Scenario I 45
7.3.2 Scenario II 47
7.3.3 Scenario III 48
8 CONCLUSION 49
REFERENCES 50
APPENDICES 53

LIST OF FIGURES

Figure 1 Airport Airside and Landside Components 7
Figure 2 Map View of DTW Airport 11
Figure 3 DTW Airport Layout 12
Figure 4 Arrivals and Departures under IFR (left) and VFR conditions (right). 14
Figure 5 Stroboscope network for arrivals, scenario I 22
Figure 6 Stroboscope network for departures, scenario I 27
Figure 7 Stroboscope network for arrivals, scenario II 30
Figure 8 Stroboscope network for arrivals, scenario III 33
Figure 9 Bird's Eye View of Detroit Metro Airport 41
Figure 10 View of Airport Operations Around Concourse C of Smith Terminal 42
Figure 11 View of Airport Operations on Runway 21R (Situation 1) 43
Figure 12 View of Airport Operations on Runway 21R (Situation 2) 43
Figure 13 Smith Terminal at DTW 44
Figure 14 Delays for scenario I 46
Figure 15 Delays for Scenario II 47
Figure 16 Delays for Scenario III 48

LIST OF TABLES

Table 1 Runway Configuration Usage according to weather conditions 13
Table 2 Minimum Distance Between Aircraft Entering the Final Approach Corridor 16
Table 3 Minimum Time Between Successive Departures..... 17
Table 4 Approach Speed and Runway Occupation Times (ROT)..... 17
Table 5 Arrival and Departures Rates as Function of Time of Day 18
Table 6 Animation Command Statements in Vitascope..... 35

LIST OF APPENDICES

A Aircraft Classifications

B Instrumented Airport Simulation Model

C Section of a Trace File for Visualizing Airport Operations

Chapter 1
INTRODUCTION

1.1 PROBLEM STATEMENT

Simulation modeling and visualization are of paramount importance in enabling the performance of actual field operations, leading to the most beneficial decisions and providing a pictorial tool of how precisely activities relate to one another. Several research efforts in visualization are ingrained in the construction field (Kamat and Martinez 2003). Besides the construction field, air transportation field is one of the domains where the abovementioned advantages are substantially accrued.

For the past three decades, due to the growth of the congestion at airports, airport authorities have looked at various ways to efficiently operate aircraft on limited infrastructure resources (Ioannou, Martinez and Trani 2001). It is acknowledged that the capacity of NAAS encompasses capacities of airports, airspace, airlines and assets, and air-traffic control. However, runway capacity dictated by large headways between aircraft operating in the vicinity of airports is significantly affecting the overall system capacity. Various tools and methods were thus advanced to estimate airport capacity and delay, in particular simulation and modeling techniques, which are considered as the most prevailing techniques in this area. One of the approaches to predict runway capacity and delays at airports and to picture the aircraft runway operations is by using a discrete-event operations simulations system and validating it through animation/visualization. In other words, visualizing simulated aviation operations in 3D can considerably help in validating the respective simulation models and

this can be done by connecting discrete event simulation models and CAD models of the airport resources (Kamat and Martinez 2001). It will thus be possible to easily grasp the logical performance of the airport system model after each simulation run since a very realistic situation is being reflected.

This study presents the simulation model and 3D animation of the operations at Detroit Metro Airport. The simulation model is developed in STROBOSCOPE (Martinez 1996) and the 3D animation is created using VITASCOPE (Kamat 2003).

1.2 RESEARCH SCOPE AND OBJECTIVE

1.2.1 Research Scope

This study develops a framework for a special-purpose Visualization/Animation system that has been specifically designed by taking into account the requirements for the realistic visualization of airport operations. This system has been combined together with a modeling simulation system, but is independent of the simulation software being used to model the scenario of interest. The Animation system is VITASCOPE (Kamat 2003) and the simulation one is STROBOSCOPE (Martinez 1996). Prototype STROBOSCOPE models to estimate the capacity and the delays at Detroit Wayne County Airport in Romulus, Michigan were presented. Each of these models illustrating a different runway performance for arrivals can be implemented as a system that uses the strengths of four separate applications. STROBOSCOPE was used as the simulation engine. STROBOSCOPE objectives are 1) modeling the operation through number crunching, 2) creating the trace files needed for animation and 3) creating the numbers behind the output tables and charts. Microsoft Visio

was used as the graphical representation of all arrivals and departures by means of all the master shapes that reside in the stencil and the shape-sheet formulas they contain. Excel can be used as the output mechanism for tabular data and charts. VITASCOPE was used for dynamic output based on the networking system of the STROBOSCOPE model and the trace files generated. STROBOSCOPE simulation model will be responsible for assembling the models networks, for assembling a CAD model of the airport to be used as the layout in the VITASCOPE animation as well as enclosing all the necessary commands that generate the VITASCOPE animation trace files. It will also include many instructions that will generate output files useful to set up all the data tables and charts. So, basically static and dynamic outputs will be generated by the STROBOSCOPE simulation of the airport operations. The static output is exemplified through the delay and capacity parameters for the particular runway performance whereas the dynamic output is in the form of VITASCOPE animation trace files that can be used to animate the airport operations in 3D.

1.2.2 Research objective

The objective of this study is to provide insight into the relative predictions of models and animations that are used to predict parameters of interest to air transportation systems, particularly Detroit Metro Airport. These parameters include airport capacity and delays for the particular configuration and schedule combination. Giving these parameters, detailed airport performance is revealed. The proposed system supported model definition by defining elements such as runways, runway exits, taxiway segments, and gates. Tools and techniques were used to design and implement the system. These tools include STROBOSCOPE as a simulation engine, Visio for the graphical model definition, Excel for tabular and graphical output, and VITASCOPE for dynamic output. A 3D Visualization Animation to visualize

modeled airport operations was generated. The 3D animation served as verification, validation tool since it included an animation of the simulated system where the aircraft can be seen moving on the runways as well as approaching the airport vicinity.

Chapter 2
PREVIOUS WORK ON AIRPORT OPERATIONS SIMULATION AND VISUALIZATION

Previous research efforts have been advanced to study aircraft runway operations at airports with the development of several macroscopic and microscopic, fast-time simulation models. Macroscopic models such as the Airport Capacity Model (ACM), RDSIM, and DELAYS developed at MIT and the Runway Capacity Model developed by LMI can be used to make policy decisions regarding the best runway operational practices at an airport. Microscopic models such as the Total Airport and Airspace Model (TAAM) and SIMMOD – the FAA airport and airspace simulation model, can handle detailed runway operations but at an added computational and detailed user cost (Odoni 2000).

Other research conducted airport simulations using High Level Architecture (Adelantado and Brunet 2001). The main purpose was to design an airport modeling and simulation infrastructure aiming at experimenting and validating some solutions to maintain an average level of aircraft movements whatever the weather conditions are. Main features of the airport modeling and simulation infrastructure were discussed and the ground sensor modeling approach was proposed to simulate aircraft localization.

Simulation models were also developed to analyze the daily taxi and takeoff operation of aircraft at the UPS Louisville Park. The model assists planners in developing aircraft

departure schedules that minimize taxi and ramp delay times (Ford,Ottman and Reinhardt 1999). The taxi simulation model was developed and validated using Arena .

Previous research was also done on the validation of an airport simulation model (Gilsinn 1976). Validation of an airport simulation model, called DELCAP for DELay CAPacity, the two quantities which it measures, for use in estimating the traffic rates attainable at major busy U.S. airports were described. The simulation model out-puts are compared to those of other models for simple cases to which both apply and to actual throughput data for several airports, with differences usually less than 6 to 8 percent.

Chapter 3

OVERVIEW ON AIRPORTS PERFORMANCE

3.1 INTRODUCTION

Over the years, airport performance measurement has been one of the newest topics among airport directors. A small, yet growing number of airports have established formal performance measurement systems. Determining how airports perform is sometimes critical and shaping the capacity of an airport is a complex issue. Several elements of the airport facility have to be examined, namely airside and landside components. The airport landside includes the terminal complex and access system, which provide transition between ground and air transportation modes. Airside facilities refer to the number and orientation of runways, taxiways and the location of terminal areas relative to runways. Figure 1 is an illustration of the two airport components.

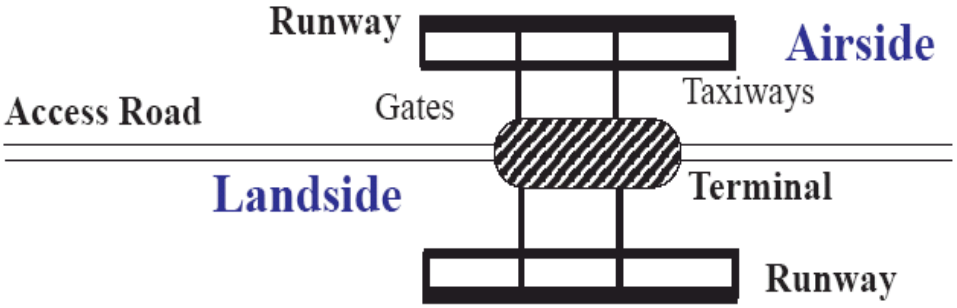


Figure 1 Airport Airside and Landside Components
[Source: http://128.173.204.63/courses/cee5614/cee5614_pub/Airport_capacity.pdf]

The focal point of this study is the analysis and modeling of the processes and operations carried out in the airfield system. Airfield requirements include the need for those facilities related to the arrival and departure of aircraft. These facilities are comprised of the following items:

- Runways and Taxiways
- Aircraft Mix
- Meteorological Conditions and Approach Procedures

3.2 RUNWAYS AND TAXIWAYS

The layout of the runways and taxiways directly affects an airfield's capacity. Aircraft use runways to land and depart at an airport. The location and orientation of the runways are not the main concern but the percent of time that a particular runway or combination of runways is in use and the length, width, weight bearing capacity, and instrument approach capability of each runway at the airport . All these parameters determine which type of aircraft may operate on the runway and if operations can occur during poor weather conditions. Aircraft approaching the vicinity of an airport are not allowed to land unless they are giving permission by air traffic controllers. After obtaining permission to land, aircraft enter the common approach path; land, roll and finally exit to a taxiway. Taxiways have also significant impact on airside capacity. They provide, in addition to the access between terminals and runways, safe and efficient use of the airside. Exit taxiways in particular are of considerable magnitude since the number and location of exits directly determines the runway occupancy time of an aircraft. For aircraft departures, aircraft wait on a taxiway and can not enter the runway, accelerate and take off before instructions are delivered.

3.3 AIRCRAFT MIX

Aircraft mix refers to the speed, size, and flight characteristics of aircraft operating at the airport. Aircraft are generally classified according to three important criteria in airport engineering:

- Geometric design characteristics (FAA). Design groups are A,B,C,D and E
- Air Traffic Control operational characteristics (approach speed criteria). Design groups are I, II, III, IV, V and VI.
- Wake vortex generation characteristics. Groups are light, medium and heavy.

For more details about aircraft groups refer to Appendix A.

The mix index of the aircraft that use the runway determines which exit to take. Heavy aircraft for example, in case of wake vortex classification, comparing to lighter aircraft, will certainly take the exit that is furthest away from the runway threshold since their runway occupancy time is higher and by consequence the aircraft will roll beyond the nearest exits and take one of the other exits to clear the runway. Another point involving aircraft mix is that as the mix of aircraft operating at an airport increases to include larger aircraft, airfield capacity begins to diminish. This is due to larger separation distances that must be maintained between aircraft of different speeds and sizes.

3.4 METEOROLOGICAL CONDITIONS AND APPROACH PROCEDURES

Meteorological conditions are another significant factor affecting airfield capacity. Airport capacity is usually highest in clear weather, when flight visibility is at its best. As weather conditions get worse and visibility is diminished, airfield capacity is reduced and the spacing of aircraft must increase to provide allowable boundaries of safety. By increasing the distance between aircraft the number of aircraft which can operate at the airport during any given period

shrinks. This consequently reduces overall airfield capacity. There are three categories of weather conditions:

- Visual Flight Rule (VFR) conditions includes minimum for distance visibility, ceilings (for takeoffs and landings), and cloud clearances. Under VFR conditions, pilots can see so far and are permitted to approach, land, or take off without relying on their instruments to fly safely but by visual reference. Under VFR rules, independent simultaneous arrivals can be conducted with at least 700ft between runway centerlines if no wake vortex effect is present.
- Instrument Flight Rule (IFR) conditions are weather conditions that do not meet the minimum visibility requirements for VFR. In such conditions pilots must rely on instruments for navigation and guidance to the runway and will rely entirely on air traffic control rules and procedures for safe separation between aircraft. As mentioned above, this leads to increased distances between aircraft which diminishes airfield capacity. Under IFR conditions, simultaneous departures can be conducted if two parallel runways are located 2,500 ft. The same applies to simultaneous arrival-departures case. But simultaneous arrivals can be carried out if the centerline distance is 4,300 ft.
- Poor Visibility Conditions (PVC) exist when the cloud ceiling and/or visibility is below minimum requirements prescribed by the instrument approach procedures for the airport. In this case, the airport is closed to arrivals.

Chapter 4

ABOUT DETROIT METROPOLITAN WAYNE COUNTY AIRPORT

4.1 INTRODUCTION

Detroit Metropolitan Wayne County Airport (DTW) is an airport in Romulus, Michigan, located 20 miles southwest of downtown Detroit, Michigan and can be accessed by I-94 directly. Figure 2 is a map view showing the location of the airport.

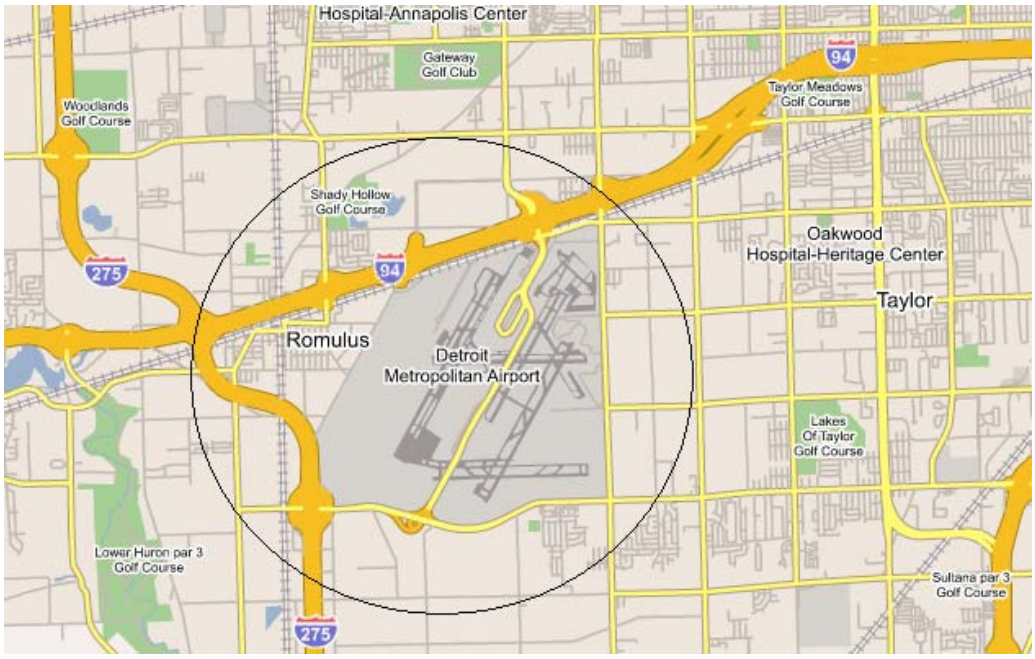


Figure 2 Map View of DTW Airport
[Source: http://maps.google.com/]

In 2004, DTW was the world's tenth busiest airport giving the number of aircraft arrivals and departures and was the nineteenth busiest passenger airport in the world. In 2002, the McNamara Terminal opened it doors for flight operations. The $ 1.2-billion McNamara Midfield Terminal project's biggest contribution to Metro's operations was the construction of a fourth parallel, also known as a main, runway (Fricker 2002).

4.2 AIRPORT LAYOUT

Figure 3 shows the general airport layout for DTW.

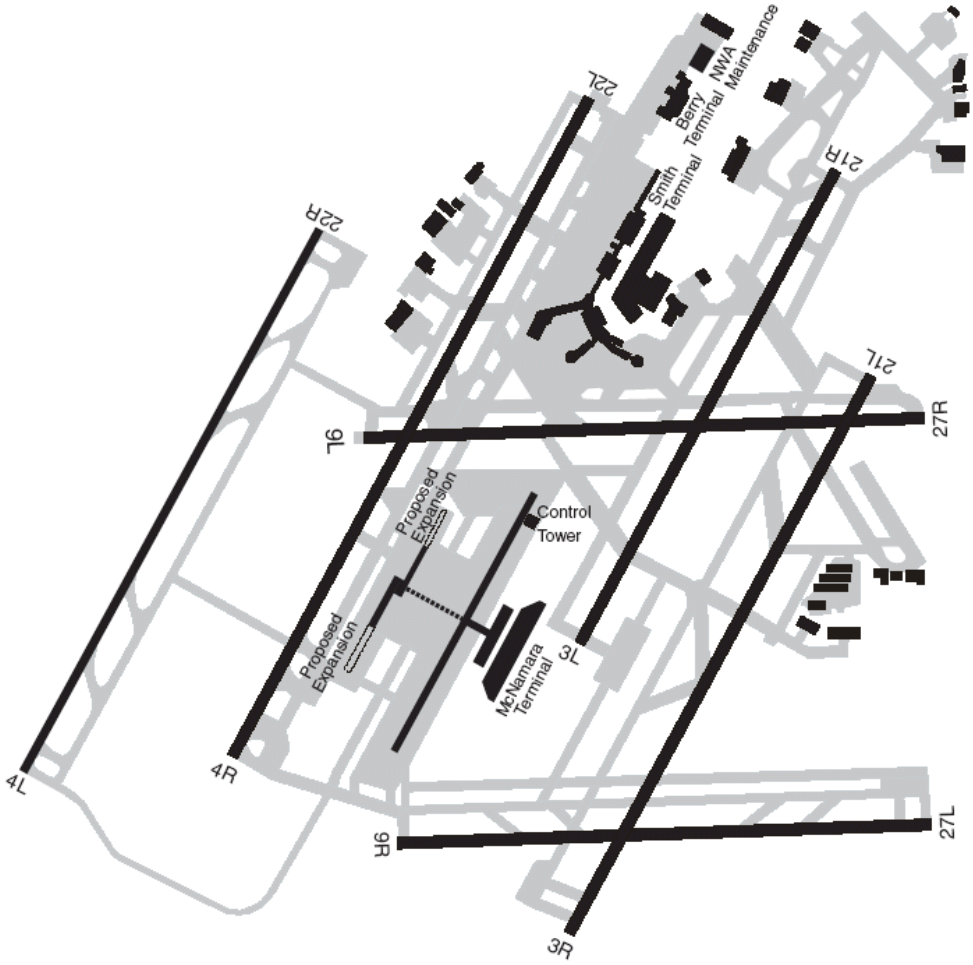


Figure 3 DTW Airport Layout
[Source: http://www.answers.com/topic/detroit-metropolitan-wayne-county-airport.]

The airport has six runways:

- Four main parallel runways oriented on a northeast-southwest heading : Runway 4R-22L is 12,001 feet long, Runway 4L-22R is 10,000 feet long, Runway 3L-21R is 8,500 feet long and Runway 3R-21L is 10,000 feet long. Runway 4L-22R is the new runway that was commissioned on December 11, 2001. With the new runway, more traffic than the

initial airspace design allows is being handled. DTW airport's new configuration (four parallel runways) increased the airport's potential capacity (Boesel and Bodoh 2004).

- Two crosswind runways oriented on an east-west heading: Runway 9L-27R is 8,700 feet long, and Runway 9R-27L is 8,500 feet long. These runways, being crosswind, are rarely used, and therefore were not taken into consideration in this study.

There are three passenger terminals located north of Runway 9L-27R, between Runways 4R-22L and 3L-21R, from which aircraft taxi in when clearing the runway and taxi out to depart.

- Two double-loaded concourses provide 97 gates at the McNamara Terminal.
- The M. Berry International Terminal provides an additional four gates for charters
- L. C. Smith Terminal provides 38 gates for other scheduled airlines.

4.3 RUNWAY CONFIGURATION

This section reflects the different runway configurations at Detroit Airport based on two meteorological conditions, IFR and VFR conditions. According to local weather data, IFR conditions occur 10 percent of the time and VFR conditions exist 74 percent of the time. Table 1 represents the existent runway configurations for both arrivals and departures based on the weather conditions.

Table 1 Runway Configuration Usage according to weather conditions

Weather Conditions	Runway Configuration
IFR	Arrivals on Runways 21L,22R Departures on 21R, 22L
VFR	Arrivals on Runways 21L,22L,22R Departures on 21R, 22L

[Source: http://www.answers.com/topic/detroit-metropolitan-wayne-county-airport.]

Figure 4 is an illustration of the two different runway configurations aforementioned.

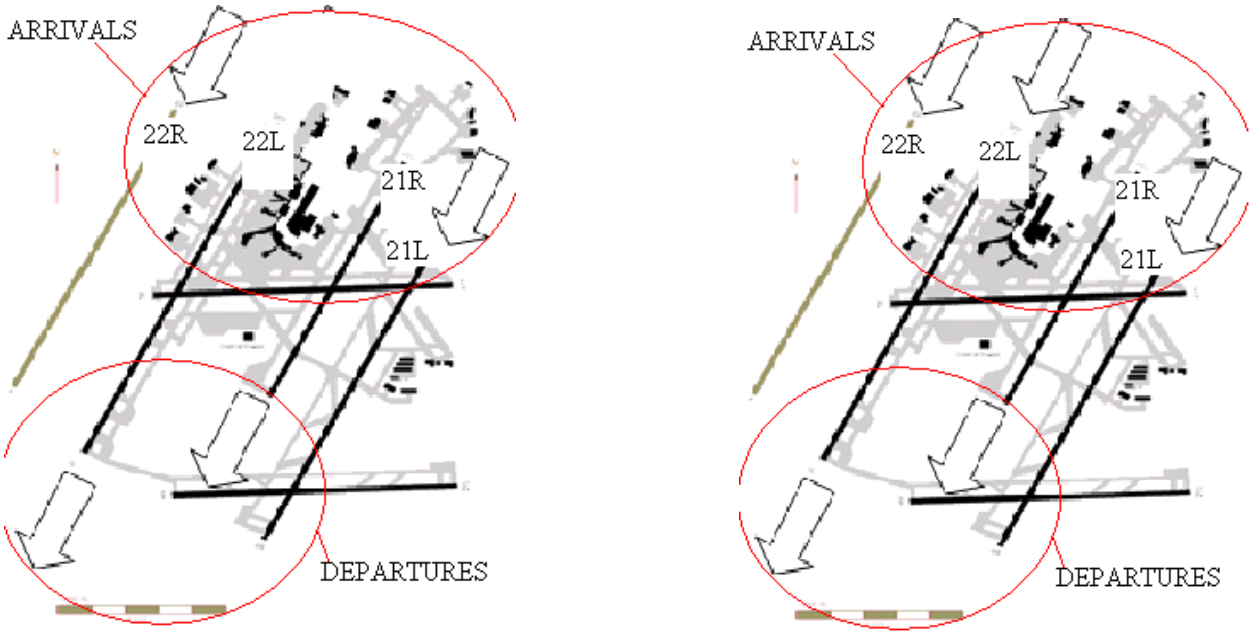


Figure 4 Arrivals and Departures under IFR (left) and VFR conditions (right).

Under IFR conditions, runways 22R and 22L can process simultaneous arrivals-departures since the centerline distance is approximately 3000 ft (> required distance=2500 ft). The same applies to Runways 22L and 21R that process simultaneous departures because the distance is 3600 ft. But, this does not apply to runways 21R and 21L because the centerline distance is 2000 ft.

Under VFR conditions, simultaneous arrivals-departures can be conducted on runways (22R-22L) and (21R-21L). But in the case of runway 22L, priority is accorded to arrivals over departures and simultaneous arrivals on runways 22L-22R can be carried out.

Chapter 5

SIMULATING RUNWAY OPERATIONS AT DTW

5.1 MODEL PARAMETERS AND ASSUMPTIONS

This section illustrates the parameters that were used to create the desired model for the DTW airport. These parameters were extracted from the previous research effort “Modeling Air-Side Airport Operations Using General-Purpose Activity-Based Discrete-Event Simulation” (Ioannou, Martinez and Trani 2001). The common approach path was assumed to be 15 km in length. The minimum separation distances between successive aircraft, which air traffic controllers comply with to account for wake turbulence, depend on the types of the aircraft. They also include a “buffer” distance of 2100 meters that acts as a safety factor. But since it is subject to measurement errors on the part of the air traffic controller, the actual buffer is assumed to be normally distributed with a mean of 2100 meters and a standard deviation of 1260 meters, but truncated two standard deviations at either side of the mean. The minimum distance between successive aircraft is shown in Table 2. When the trailing airplane is slower than the leading airplane, the minimum separation occurs when the airplane that follows enters the common approach path. When the trailing airplane is faster than the leading airplane, the minimum separation occurs when the leading airplane crosses the runway threshold. In addition to the minimum distance, Table 2 shows the necessary separation between aircraft when the trailing airplane enters the common approach path. In Table 2 and throughout this study, aircraft are classified according to the wake vortex criteria: light, medium and heavy. This classification is based on aircraft maximum gross mass. Light aircraft have a maximum takeoff mass of less than

18,635 kg. Medium size aircraft weigh up to 116,000 kg and heavy aircraft are those with a maximum takeoff mass above 116,000 kg.

Table 2 Minimum Distance Between Aircraft Entering the Final Approach Corridor

Following Airplane Type	Leading Airplane Type	Minimum Distance (meters)	Minimum Distance When Trailing Airplane Enters (meters)
Heavy	Heavy	6000	6000
Heavy	Medium	6000	6840
Heavy	Light	6000	8760
Medium	Heavy	9000	9000
Medium	Medium	6000	6000
Medium	Light	6000	8120
Light	Heavy	12000	12000
Light	Medium	9000	9000
Light	Light	6000	6000

The arrival-departure distance is assumed to be 3200 meters so that a departing airplane terminates its runway occupation before the arriving aircraft touches the runway. Since departing aircraft create wake turbulence that affects other aircraft departing on the same runway, minimum times between successive departures have to be set to account for differences in takeoff speed (i.e., to prevent a fast plane overtaking a slow plane) and for wake turbulence effects. These times are shown in Table 3.

Table 3 Minimum Time Between Successive Departures

Trailing Plane Type	Leading Plane Type	Minimum Time Between Successive Departures (seconds)
Heavy	Heavy	60
Heavy	Medium	90
Heavy	Light	120
Medium	Heavy	60
Medium	Medium	60
Medium	Light	90
Light	Heavy	60
Light	Medium	60
Light	Light	60

The speed of landing aircraft while in the common approach path depends on the type of aircraft. The time of runway occupation is normally distributed and depends on the type of aircraft and on whether the aircraft is landing or taking off. Table 4 shows the various approach speeds and occupation times.

Table 4 Approach Speed and Runway Occupation Times (ROT)

Plane Type	Approach Speed (m/sec)	Landing ROT Mean (seconds)	Landing ROT s. dev (seconds)	Takeoff ROT Mean (seconds)	Takeoff ROT s. dev (seconds)
Heavy	75	55	6	38	4
Medium	68	50	10	43	6
Light	52	45	10	50	6

The aircraft mix for this simulation study is 33% heavy, 33% medium size and 33% light, but can be easily modified in the model to reflect the actual aircraft mix at DTW. The DTW arrival and departure schedule shown in Table 5 was obtained from the BTS database by looking up the "DETAILED STATISTICS" for arrivals and departures according to each airline then computing the daily averages for the busy month of December 2004.

Table 5 Arrival and Departures Rates as Function of Time of Day

Time of day (hr)	Arrivals per Hour	Departures per Hour
12 PM - 1 AM	3.94	0
1 AM - 2AM	0	0
2 AM - 3 AM	0	0
3 AM - 4 AM	0	0
4 AM - 5 AM	0	0
5 AM - 6 AM	6.55	2
6 AM - 7 AM	0	11.68
7 AM - 8 AM	10.51	20.68
8 AM - 9 AM	18.26	18.84
9 AM - 10 AM	24.60	30.13
10 AM - 11 AM	22.40	30.97
11 AM - 12 AM	32.84	8.06
12 AM - 1 PM	30.54	38.26
1 PM - 2 PM	6.51	35.65
2 PM - 3 PM	36.19	9.71
3 PM - 4 PM	26.29	38.74
4 PM - 5 PM	30.35	10.29
5 PM - 6 PM	21	43.19
6 PM - 7 PM	29.22	8.58
7 PM - 8 PM	23	42.84
8 PM - 9 PM	32.32	5.16
9 PM - 10 PM	17.16	24.97
10 PM - 11 PM	8.50	7.94
11 PM - 12 PM	6.06	0

The purpose of this simulation is to determine the expected average and maximum daily waiting times for arriving and departing airplanes for any runway configuration. This information is used to determine if the airport is capable of supporting the demands shown in Table 5 with acceptable delays.

5.2 DIFFERENT AIRPORT OPERATIONS SCENARIOS

This section discusses three different scenarios picturing possible modes of operations at Detroit Metro Airport under two meteorological conditions (IFR and VFR conditions). Under IFR conditions, one scenario was studied, whereas under VFR conditions two scenarios were considered for the same runway configuration. As previously stated, the difference between the two weather conditions resides in the arrival runway configuration, where an additional runway processes arrivals under VFR. Runways assigned for departures are the same under both weather conditions.

5.2.1 Scenario I - IFR Conditions

Under IFR conditions, two runways 21L and 22R process arrivals. Based on the runway dimensions, heavy, medium and light airplanes can land on any of these two runways. For departures, Runway 21R processes medium and light aircraft whereas 22L processes heavy ones.

5.2.2 Scenario II - VFR Conditions (case I)

In this case, three runways (Runways 21L, 22L and 22R) are used for arrivals and this applies to any aircraft type. Departures procedures meet the same requirements as under IFR conditions.

5.2.3 Scenario III - VFR Conditions (case II)

This case differs from the previous one in that only heavy airplanes land on Runway 22L whereas medium and light land on either 21L or 22 R.

5.3 STROBOSCOPE SIMULATION MODELS

5.3.1 Introduction

This section describes how STROBOSCOPE, as a discrete-event activity simulation modeling language, can be used as a tool to model the operations at DTW airport.

One of the fundamental entities in STROBOSCOPE models are resources, which move through the model's network and can represent trucks, planes, loaders or anything else needed to perform tasks. The STROBOSCOPE model in this study uses resources *Plane* to represent airplanes, *Sequencer* to represent signals, and *ArvlSchdlr* for arrival schedulers. However, their role in the development of a simulation model is passive because STROBOSCOPE models are developed from the perspective of activities, mainly Combi and Normal. Normal activities cannot be preceded by Queues and they simply start immediately after other tasks end. Instances are created without the need to check any conditions. On the other hand, Combi activities, which can only be preceded by Queues, constantly check the state of the simulation at events' discrete points to see if the conditions required for instances to be created are satisfied. Once the conditions necessary for a Combi to create an instance are satisfied, the Combi removes resources from the preceding Queues and determines the duration of the instance. By default, STROBOSCOPE removes the first available resource from each preceding queue (FIFO case). The instance is then inactive until the time when it releases the resources to the successor nodes and ends. But sometimes activity instances generate resources before their termination (BEFOREEND) so that resources that had not been attained during instance creation can be released. Another important point about Combi activities is their attribute Semaphore. In cases where Combi activities do not depend on preceding queues to start, the condition can be specified with a Semaphore. The Semaphore is a logical expression that return TRUE when

Combi can be instantiated and FALSE otherwise. Semaphores are needed to model the air-side operations discussed in this study. The auxiliary network node Fork is also needed since it is capable of modeling the path of resources or the start of the successive activities based on a probabilistic selection procedure defined by Strength in STROBOSCOPE.

5.3.2 Scenario I

5.3.2.1 Modeling Arrivals, Approach and Landing

In this case, two runways process arrivals, 21L and 22R. Based on the runway dimensions, heavy, medium and light airplanes can land on any of these two runways. The model network that reflects the activities of this case is shown in Figure 5. This network illustrates three major portions: the first one introduces airplanes to the system through arrival scheduler resource, the second models approach and landing of airplanes through resource *Plane* and the third one models the minimum separations between airplanes in the common approach path through *Sequencer* resource.

The first portion of the network comprised of the *PArrival* Combi activity; the *ArvlSchdlrs* Queue; and the *AS1*, *AS2*, and *AP1* links models the airplanes arrival to the system. Each of the twenty four resources of type *ArvSchd*, which are initially in *ArvlSchdlrs* queue, represents the information in the first two columns of the corresponding row in Table 5 defined earlier, and enables the creation of a separate instance of *PArrival*. The duration of *PArrival* is set such that each instance ends at the time at which an airplane of the corresponding time period arrives. This duration is defined in the model with the following expression:

```
DURATION PArrival
'PArrival.ArvSchdlr.i==0? PArrival.ArvSchdlr.SampledIAT:
PArrival.ArvSchdlr.NextArv';
```

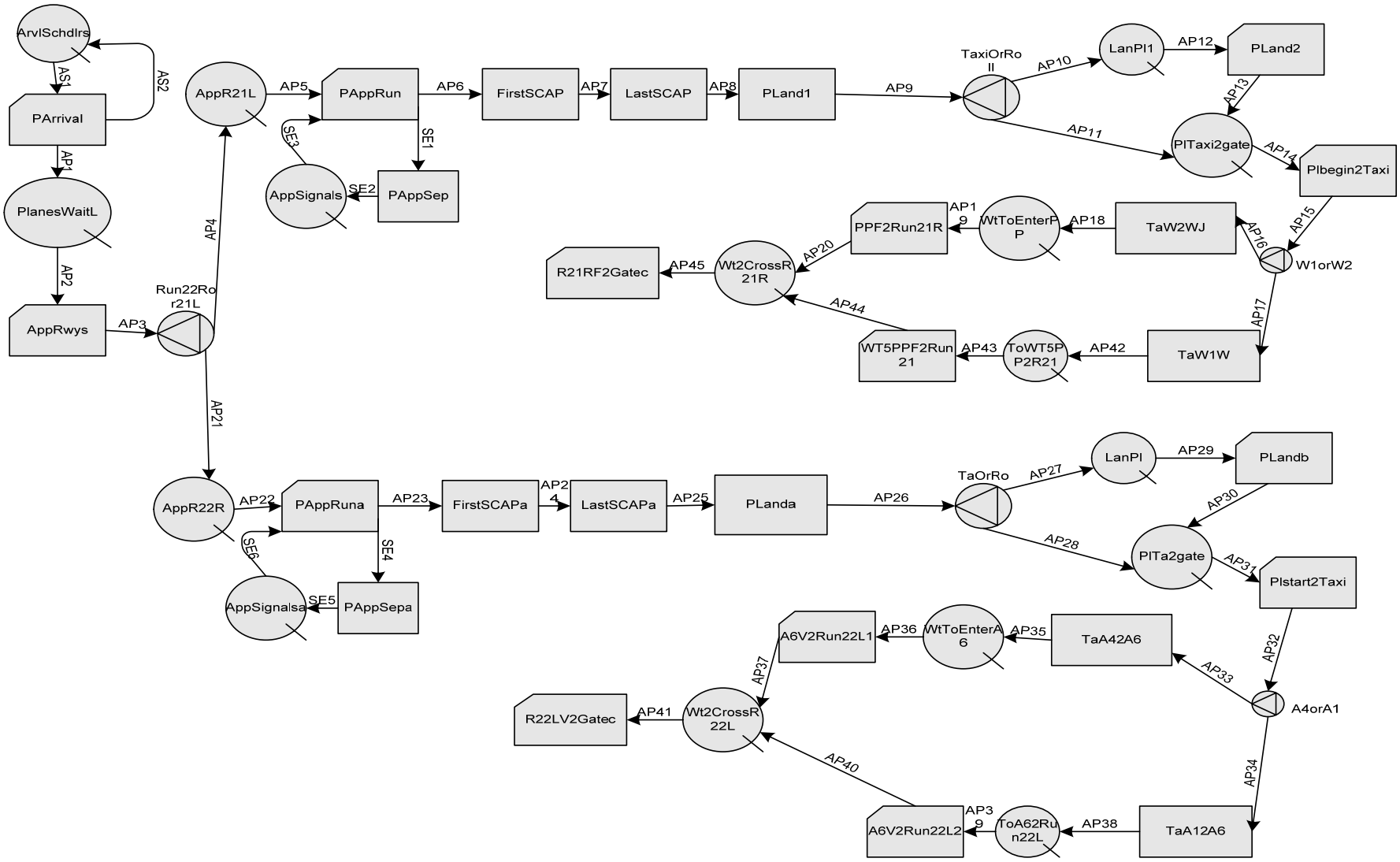


Figure 5 Stroboscope network for arrivals, scenario I

SampledIAT is the interarrival time between airplanes and is based on the rates from Table 5. *StartHr* and *EndHr* define one hour range timing for each arrival scheduler resource and they are giving in Table 5. The variable *CurHour* and the property *NextArv* which are referenced in the above expression are calculated as follows:

```
VARIABLE CurHour Mod[SimTime/3600+SimBeginHour,24];
VARPROP ArvSchdlr NextArv 'SampledIAT+CurHour*3600<EndHr*3600 ? SampledIAT:
SampledIAT+(24-(EndHr-StartHr))*3600';
```

When *PArrival* terminates, the arrival scheduler is released to *ArvlSchdlrs*, creating by this another instance of *PArrival*. Arrival schedulers are thus constantly circulating in this part of the network and constantly introducing arriving airplanes to the system. Each time an instance of *PArrival* terminates, an airplane of the appropriate type (*Light*, *Medium*, or *Heavy*) is generated and placed in the *PlanesWaitL* queue. The type of the airplane is determined such that there is an equal probability of the plane being light, medium, or heavy. But sometimes, as previously stated, activity instances generate resources before their termination and in this case *PArrival* generate the next planes of the appropriate type to arrive as follows:

```
VARIABLE NextArvType 'sRnd[1]<=1/3 ?Heavy:sLastRnd [1]<=2/3 ? Medium:Light' ;
BEFOREEND PArrival  GENERATE   1  NextArvType ;
```

The second portion of the network represents the system logic that controls airplanes approaching the runway and landing on either 21L or 22R. This is achieved in the model by first defining the property *LandRun* for the characterized resource *Plane* and assigning it to any of the runways based on a probabilistic selection (in this case equal probability). The next step is to use the fork *Run22Ror21L* and set the conditions on links *AP4* and *AP21*. The implementation of this is defined in STROBOSCOPE as follows:

```
ONDRAW AP2 ASSIGN LandRun 'sRnd[1]<=0.5?R21L:R22R' ;
STRENGTH AP4 ' AppRwys.Plane.LandRun==R21L' ;
STRENGTH AP21 'AppRwys.Plane.LandRun==R22R' ;
```

AppRwys is a zero-duration dummy activity that marks the entry of airplanes into the common approach path either for runway 21L or 22R.

From this point, all tasks performed on each runway are almost the same. In other words, the system logic behind the operations on both runways is the same, and thus only operations carried out on runway 21L are considered in this study. Before proceeding with this portion of the network, it is important to first introduce the third one. The third portion of the network comprised of *AppSignals*, *PAppSep* and the *SE1*, *SE2* and *SE3* links controls the separation distances between airplanes in the common approach path. *PAppSep* takes place immediately after *PAppRun* concludes and its duration is set to the minimum lead-time of the corresponding plane. *MinLeadTime* is a property of *Plane,* which specifies the minimum separation time between the arriving plane and the next plane to arrive. This value is determined by looking up in Table 2 (which is represented by a matrix in STROBOSCOPE), adding a stochastic buffer, and dividing by the approach speed. This is defined in the model with the following expression:

```
ONRELEASE AP1 ASSIGN MinLeadTime
'Min [ComAppL, (MatrixIJ[NextArvType==Heavy ?0:NextArvType==Medium?1:2, Type]
+Max[MinBufferd,Min[sNormal[BufferDist,BuffDistsd,2],MaxBufferd]])]/AppSpeed;
```

It is after this time has passed that a resource is released to *AppSignals*, thus preventing other airplanes that may be in *AppR21L* to begin approaching during that time. *PAppRun*, a zero-duration dummy that marks the entry of an airplane into the common approach path toward runway 21L, can then start whenever *both AppSignals* and *AppR21L* queues contain at least one resource each (first available resource in each is removed, FIFO). The common approach path is

broken into two parts, *FirstSCAP* and *LastSCAP*. *FirstSCAP*, which takes place immediately after *PAppRun* concludes, represents an airplane traversing the first 11,800 m of the common approach path. *LastSCAP* starts immediately after *FirstSCAP* and represents an airplane traversing the last 3200 m of the common approach path. The arriving airplane then lands on the runway and starts to roll on the landing run. Each airplane has properties determined from its type that correspond to those specified in Table 4. However, depending on the type of the plane and the sampled duration of the ROT, the arriving plane can either use the nearest possible exit and clears the runway or roll beyond the first possible exit and takes the next exit. The first case applies to light and medium airplanes whereas the second case applies to heavy ones. This is achieved in the model by defining the fork *TaxiOrRoll* and setting the conditions on links *AP10 (heavy)* and *AP11 (medium &light)* as follows:

```
STRENGTH AP10  ' (PLand1.Plane.Type==0) ? 1: 0' ;/ type 0 refer to heavy
STRENGTH AP11  ' ((PLand1.Plane.Type!=0)) ? 1: 0' ; /in this case its either
type 1 or 2 (medium or light)
```

Upon exiting the runway, the aircraft uses the best feasible taxiways to travel from the exit to the designated parking gate. Heavy airplanes travel on a different taxiway *(WT5PPF2Run21R)* than medium and light airplanes *(PPF2Run21R)*. Thus, the fork *W1orW2* is inserted and conditions are set as follows:

```
STRENGTH AP16  ' ((Plbegin2Taxi.Plane.Type!=0))?1:0';/in this case its either
type 1 or 2 (medium or light)
STRENGTH AP17  ' (Plbegin2Taxi.Plane.Type==0)?1:0';/type 0 refer to heavy
```

A taxiing airplane is always aware of the operations that take place on the airport. For example, an airplane will obviously not cross a runway when there are arrivals or departures being processed on that runway. In our case, airplanes taxiing from R21L to concourse C in Smith Terminal can not cross runway 21R when there are departures conducted on it. This is achieved in the model by using a semaphore for the activity *R21RF2Gatec* as in the following expression:

```
SEMAPHORE R21RF2Gatec '!RollingR21R.CurInst & !TakeOffR21R.CurInst&
!R21RF2Gatec.CurInst' ;
```

After crossing runway 21R, airplanes travel to gate in concourse C, which is represented by *R21RF2Gatec* in the model.

5.3.2.2 Modeling Departures

The model network that describes the logic of airplanes departing is defined in figure 6. This network illustrates two major portions: the first one introduces departing airplanes to the system through arrival scheduler resource and the second models departures of airplanes through resource *Plane.*

Airplanes departing are generated independently of arrivals according to the rates specified in Table 5 and are placed in the *PlanesWaitD* queue. Departures are modeled by the portion of the network comprised of the *PDeparture* Combi activity, the *DptSchdlrs* Queue, and the *DS1*, *DS2*, and *DP1 links* in much the same way as the arrivals to the system are modeled. This is defined in the model as follows:

```
DURATION PDeparture'PDeparture.ArvSchdlr.i==0?
PDeparture.ArvSchdlr.SampledIAT:PDeparture.ArvSchdlr.NextArv';
VARIABLE NextDptType 'sRnd[1]<=1/3 ? Heavy:sLastRnd [1]<=2/3?Medium: Light' ;
BEFOREEND PDeparture  GENERATE   1  NextDptType ;
```

A generated departing plane is assigned a particular runway for departure at the time of its creation. In this case, two runways process departures, 22L and 21R. The assigned runway depends on the current runways designated for processing departures and the type of the departing airplane. Heavy airplanes depart on 22L and light and medium on 21R.

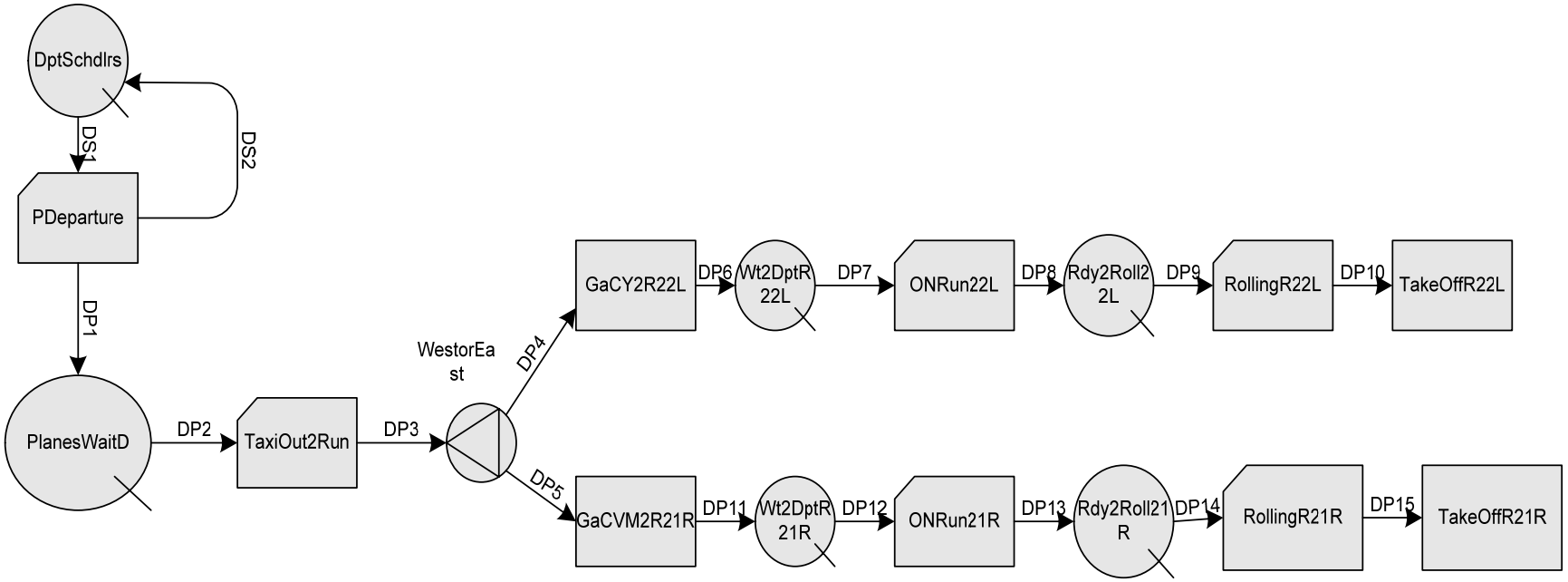


Figure 6 Stroboscope network for departures, scenario I

This is achieved in the model by creating the fork *WestorEast* and setting the probabilistic conditions on links *DP4* and *DP5* as follows:

```
STRENGTH DP4  '(TaxiOut2Run.Plane.Type==0)?1: 0' ;/ type 0 refer to heavy
STRENGTH DP5  ' ((TaxiOut2Run.Plane.Type!=0)) ?1: 0' ; /in this case its
either type 1 or 2 (medium or light)
```

An airplane ready to depart uses the optimum taxiway path to travel from the parking gate to the assigned runway. Thus, heavy planes travel heading west and medium and light heading east.

An airplane departing from any of the runways is cleared for departure when there is no other traffic on the assigned departure runway. This is achieved in the model by setting semaphores for both activities *ONRun22L* and *ONRun21R* as well as *RollingR22L* and *RollingR21R*, which are defined in the model as follows:

```
SEMAPHORE ONRun22L
'!ONRun22L.CurInst&!RollingR22L.CurInst&!Rdy2RollR22L.CurCount' ;/ heavy
SEMAPHORE ONRun21R
'!ONRun21R.CurInst&!RollingR21R.CurInst&!Rdy2RollR21R.CurCount' ;/medium and
light

PRIORITY RollingR22L 10;
SEMAPHORE RollingR22L '!R22LV2Gatec.CurInst&!TakeOffR22L.CurInst' ;

PRIORITY RollingR21R 10;
SEMAPHORE RollingR21R   '!LastSCAP.CurInst&!PLand1.CurInst&
!R21RF2Gatec.CurInst&!TakeOffR21R.CurInst' ;
```

Rolling activities, in both cases, are given priority over runway crossings (*R22LV2Gatec* and *R21RF2Gatec*). In addition, they can not start if there is a plane taking off. For rolling activity *RollingR21R,* additional conditions are set because under IFR conditions, runways 21R and 21L can not process simultaneous arrivals-departures since the centerline distance is approximately 2000 ft (< required distance=2500 ft). Thus, a plane ready to depart from runway 21R, must be cleared for rolling when there are no arrivals to be conducted on runway 21L (arrivals are first allowed to be conducted).

A departing plane, after being cleared for departure, then occupies the runway for the sampled ROT duration before taking off. Since departing aircraft create wake turbulence that affects other aircraft departing on the same runway, minimum times between successive departures (shown in Table 3 and represented by a matrix in STROBOSCOPE) have to be set to account for differences in takeoff speed and thus prevent a fast plane overtaking a slow plane and avoid wake turbulence effects. This is defined in the model through the durations of both activities *TakeOffR22L* and *TakeOffR21R* which are calculated as follows:

```
SAVEVALUE LeadingPlTypeR22L -1 ;
DURATION TakeOffR22L 'Max[0,LeadingPlTypeR22L==-1 ? 0:
SepSuccDpt[TakeOffR22L.Plane.Type,LeadingPlTypeR22L]-
sNormal[TakeOffR22L.Plane.ToffROTm,TakeOffR22L.Plane.ToffROTsd,3]]';
ONSTART TakeOffR22L  ASSIGN LeadingPlTypeR22L TakeOffR22L.Plane.Type;
```

The duration for takeoff is the maximum between 0 and the difference between minimum times and ROT duration before taking off. In other words, the time during which airplane is occupying the runway before taking off added to the takeoff duration should equal the minimum times between successive departures. This way, no plane overtakes another one and wake vortex is avoided.

5.3.3 Scenario II

5.3.3.1 Modeling Arrivals, Approach and Landing

In this case, three runways process arrivals, 21L, 22R and 22L and heavy, medium and light airplanes can land on any of these three runways. The simulation network that corresponds to this scenario, Figure 7 is the same as in Figure 5 but with an additional portion (middle branch) accounting for runway 22L. The changes to the model due to this additional runway are represented in the model as follows:

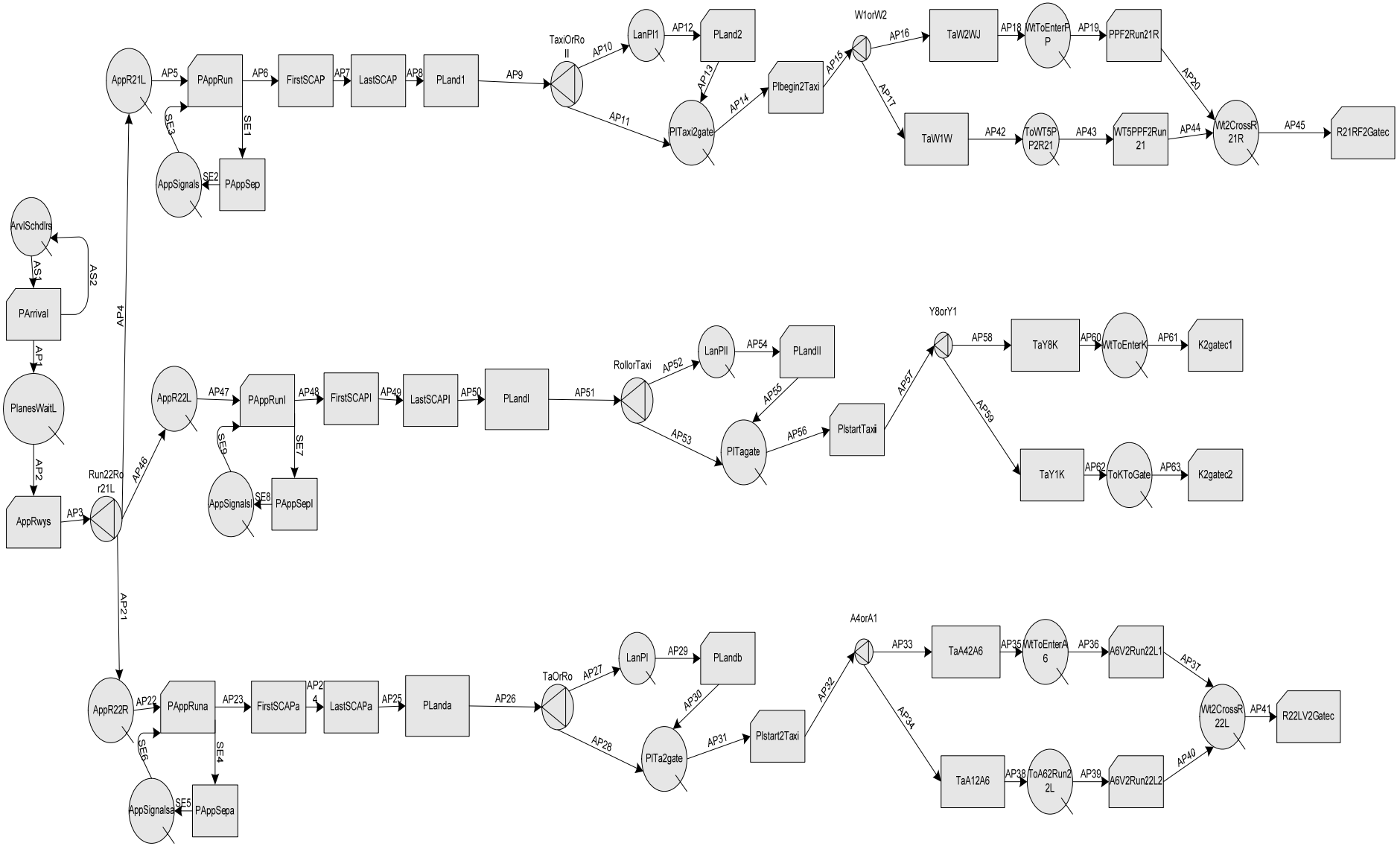


Figure 7 Stroboscope network for arrivals, scenario II

```
VARIABLE R21L 1;
VARIABLE R22R 2;
VARIABLE R22L 3;

ONDRAW AP2 ASSIGN LandRun 'sRnd[1]<=1/3?R21L:sLastRnd [1]<=2/3?
R22R:R22L';
STRENGTH AP4 ' AppRwys.Plane.LandRun==R21L' ;
STRENGTH AP21 'AppRwys.Plane.LandRun==R22R' ;
STRENGTH AP46 'AppRwys.Plane.LandRun==R22L' ;
```

In this case, the property *LandRun* for the characterized resource *Plane* is assigned a third new variable representing runway 22L based on a probabilistic selection (in this case equal probability=33%). Moreover, the fork used is now *R22R21LorR22L* and a new condition on link AP46 is set.

5.3.3.2 Modeling Departures

The simulation network that models departures under this scenario is the same as in Figure 6. But in this case, new conditions are added to the semaphores related to departures activities performed on runway 22L since this runway is processing arrivals and departures. This is defined in the STROBOSCOPE code as follows:

```
SEMAPHORE ONRun22L '!ONRun22L.CurInst & !RollingR22L.CurInst
&!Rdy2RollR22L.CurCount &!R22LV2Gatec.CurInst& !LastSCAPI.CurInst &
!PLandI.CurInst& !PLandII.CurInst&!TakeOffR22L.CurInst' ;
```

These new conditions are related to all arrivals activities performed on runway 22L. An airplane departing from this runway is cleared for departure when the minimum prescribed separation arrival and departure criteria have been met and there is no other traffic on the assigned departure runway. However at the same time, conditions are removed from semaphores for departure activities performed on runway 21R since operations are conducted under VFR conditions. This is reflected in the model with the following expression:

```
SEMAPHORE RollingR21R '!R21RF2Gatec.CurInst&!TakeOffR21R.CurInst' ;
```

In this case, there are no constraints concerning the arrival activities performed on the parallel runway 21L as opposed to the other scenario where the semaphore is as follows:

```
SEMAPHORE RollingR21R
'!LastSCAP.CurInst&!PLand1.CurInst&!R21RF2Gatec.CurInst&!TakeOffR21R.CurInst'
```

5.3.4 Scenario III

5.3.4.1 Modeling Arrivals, Approach and Landing

The activity-based network for the simulation model for scenario III is shown in Figure 8.

The change to this model comparing to scenario II model, is that heavy airplanes land on runway 22L and medium and light airplanes land on any of the runways 21L, 22R and this is defined in STROBOSCOPE as follows:

```
ONDRAW AP2 ASSIGN LandRun 'Type==0?R22L:sRnd [1]<=0.5?R22R:R21L' ;
```

In this case, for each runway no forks are needed to model the path of resource *Plane* based on a probabilistic selection procedure. This is because each runway processes only planes of same type, whether heavy or medium and light. By consequence, all forks are removed and all activities and queues which are not related to the plane type allowed to land on this specific runway are also excluded.

5.3.4.2 Modeling Departures

The simulation network that models departures under this scenario is the same as in Figure 6 previous one (scenario II) and the STROBOSCOPE code also remains the same.

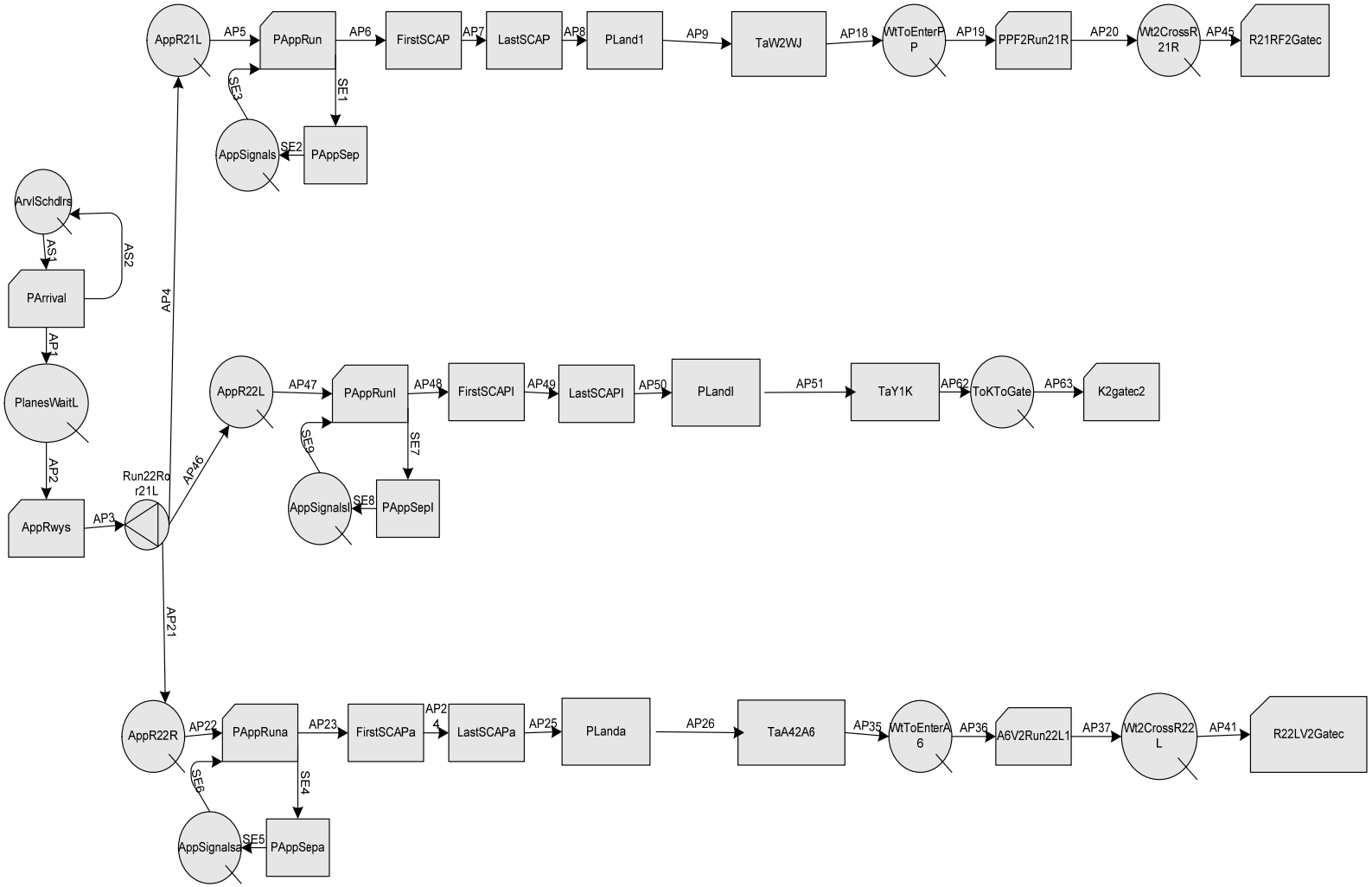


Figure 8 Stroboscope network for arrivals, scenario III

Chapter 6

VALIDATING DTW AIRPORT SIMULATION MODELS USING 3D ANIMATION

6.1 INTRODUCTION: 3D ANIMATION AND OBJECTIVES

One of the primary disadvantages in the use of discrete-event simulation models is that there are no means to check the credibility of the models and the authenticity of the results (Kamat and Martinez 2003). Thus, validation of models is a very important procedure. Two main methods are used in the validation process: the examination of output and trace files, and visualization through observation of the model's 3D animation (Ford, Ottman and Reinhardt 1999), the latter was adopted in this study. Thus, 3D animation objectives are: 1) to verify that code is free of errors; 2) to validate simulation models; and 3) to ensure the veracity and credibility of models once verified and validated (Ioannou and Kamat 2005).

6.2 3D ANIMATION TOOL: VITASCOPE

The STROBOSCOPE models presented earlier are validated in this study using VITASCOPE (Kamat 2003).

6.2.1 VITASCOPE characteristics

VITASCOPE is a general-purpose, user-extensible 3D animation system designed for visualizing simulated processes in smooth, continuous, 3D virtual worlds. VITASCOPE is capable of visualizing modeled operations in 3D by connecting ASCII animation trace and 3D CAD models of the involved resources (Kamat and Martinez 2003).

VITASCOPE characteristics are: 1) maintaining an independent simulation clock; 2) allowing the user to navigate in 3D space; 3) allowing the user to jump to any desired time; and 4) permitting the viewer to start and pause the animation at any simulation time to check the trace files (Kamat and Martinez 2001).

6.2.2 Generating Vitascope Animation Commands

A VITASCOPE trace file consists of sequential animation command statements.

Table 6 lists a few key animations commands currently available in VITASCOPE with a brief explanation of their functionality.

Table 6 Animation Command Statements in Vitascope

Statement	Functionality
TIME	Indicates simulation time at which all subsequent commands take place
CLASS	Associates class of simulation entities with their geometric description contained in CAD file
CREATE	Creates specific simulation objects by instantiating predefined classes.
PLACE	Places simulation objects at particular locations or at beginning of resource movement paths.
MOVE	Simulation objects begin moving on resource movement paths at time specified by preceding time statement.

[Source:http://scholar.lib.vt.edu/theses/available/etd-10232000-19390056/unrestricted/Thesis.pdf]

The trace file also contains statements such as PATH and NONDIRECPATH that define resource movement trajectories for the animated simulation entities.

Simulation models need to be instrumented to generate VITASCOPE animation commands during a simulation run. This can be illustrated using the following example (Kamat and Martinez 2001). The statement below, for example, tells STROBOSCOPE to add two lines of text to VITASCOPE trace file every time a truck starts to enter the dump area (EnterDmpArea activity):

```
ONSTART EnterDmpArea PRINT ATF
"TIME %.2f\059
MOVE Truck%.Of EnterDmpArea %.2f\059\n"
SimTime EnterDmpArea.Truck.ResNum EnterDmpArea.Duration;
```

These two lines will be written to VITASCOPE trace file numerous times, each of which will look similar to:

```
TIME 353.86;
MOVE Truck1 EnterDmpArea 50.21;
```

Once all the models are instrumented, trace files are generated. In fact, the time-ordered sequence of animation statements written out by all the activities in the model during a simulation run constitutes the trace file required to visualize the modeled operations. The size of the generated trace files depends on the amount of detail modeled and length of simulation.

6.2.3 Developing CAD Models of Simulation Objects

3D CAD models need to be imported to visualize the simulated operations. AC3D (Colebourne 2000) is one of the 3D modelers that can be used to create the 3D models required to visualize any simulated operation.

6.3 VIZUALIZING DTW AIRPORT OPERATIONS USING VITASCOPE

This section describes how VITASCOPE can be used as a tool to visualize the operations at DTW airport. Airport operations mainly involve airplanes arriving, departing and taxiing in and out from gates to runways and vice-versa. Simulation models need to be instrumented to generate VITASCOPE animation commands during a simulation run. The animation commands statements that are used in this study are the ones predefined earlier in addition to others. Model instrumentation is shown through some of the activities then a larger portion of a trace file is displayed. Snapshots of every scenario are presented.

6.3.1 PATH and NONDIRECPATH Animation Statements

The statements below define plane movement trajectories (toward runway 21R) for *AlignPath1* and *FirstSCAP*.

```
"PATH AlignPath1
      '(12477.7,1500,-11003.30)'
      '(12477.648,1500,-11003.330)'\059

NONDIRECPATH FirstSCAP
'(12477.648,1500,-11003.330)'
'(3406.164,316,-3375.419)'\059
```

6.3.2 TIME, CREATE, PLACE, MOVE and DESTROY Animation Commands Statements

The statement below, for example, tells STROBOSCOPE to add two lines of text to VITASCOPE trace file every time a plane of a specific type is released to *PlanesWaitL*. A plane is created at this moment.

```
ONRELEASE AP1 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONRELEASE AP1 PRINT VTF
            "CREATE Plane%.0f Type%.0f\059\n"
            ResNum
            Type;
```

These two lines will be written to VITASCOPE trace file numerous times, each of which will look similar to:

```
TIME 641.512843;
CREATE Plane9 Type2;
```

The time, plane number and plane type will be different each time.

Similarly, two lines of text are added to VITASCOPE trace file every time a plane of a specific type is released to *PAppRun* and thus is placed on the path when approaching the runway.

```
ONDRAW AP5 PRINT VTF
            "TIME %f\059\n" RelTime;
ONDRAW AP5 PRINT VTF
            "PLACE Plane%.0f ON AlignPath1\059\n"
            ResNum;
```

These two lines will be written to VITASCOPE trace file numerous times, each of which will look similar to:

```
TIME 1001.367849;
PLACE Plane17 ON AlignPath1;
```

The same applies to the following statement, where two lines are added to VITASCOPE every time a plane starts to enter *FirstSCAP:*

```
ONSTART FirstSCAP PRINT VTF
            "TIME %f\059\n" RelTime;
ONSTART FirstSCAP PRINT VTF
            "MOVE Plane%.0f FirstSCAP %f\059\n"
            FirstSCAP.Plane.ResNum
            FirstSCAP.Duration;
```

These two lines will be written to VITASCOPE trace file numerous times, each of which will look similar to:

```
TIME 669.777553;
MOVE Plane8 FirstSCAP 226.923077;
```

Likewise, two lines of text are added to VITASCOPE trace file every time a plane of a specific type is about to leave *R21RF2Gatec.* At this time, the plane in question is destroyed.

```
BEFOREEND R21RF2Gatec PRINT VTF
            "TIME %f\059\n"
            RelTime;
BEFOREEND R21RF2Gatec PRINT VTF
            "DESTROY Plane%.0f\059\n"
            R21RF2Gatec.Plane.ResNum;
```

These two lines will be written to VITASCOPE trace file numerous times, each of which will look similar to:

```
TIME 995.329844;
DESTROY Plane5;
```

6.3.3 CLASS, SET CLASS (RGP and AFTCLEARANCE) Animation STATEMENTS

All simulation objects, in our case planes, can be represented as VITASCOPE objects. The CLASS statement identifies the CAD file that contains the geometric representation for a particular class of VITASCOPE objects (Kamat and Martinez 2003). CAD files are in the same folder as the animation trace files. The CAD file of this study is in ac3d format.

Example: CLASS AirSide DTW.ac\059

The SET CLASS RGP (AFTCLEARANCE) statement sets the RGP offset (after clearance) for the specified class. Existing objects are unaffected and new objects inherit the class' new RGP offset (after clearance value) (Kamat and Martinez 2003).

Example:
```
SET CLASS Type0 RGP 30;
SET CLASS Type0 AFTCLEARANCE 75;
```

6.3.4 Larger Portion of a Trace file

Figure 8 shows a larger portion of VITASCOPE trace file that could be generated during a simulation run.

```
CLASS AirSide DTW.ac;
CREATE AirSide AirSide;
PLACE AirSide AT (0,0,0);
CLASS Type0 DC10.osg;
SET CLASS Type0 RGP 30;
SET CLASS Type0 AFTCLEARANCE 75;
CLASS Type1 Boeing737.osg;
SET CLASS Type1 RGP 25;
SET CLASS Type1 AFTCLEARANCE 60;
CLASS Type2 Avro.osg;
SET CLASS Type2 RGP 25;
SET CLASS Type2 AFTCLEARANCE 60;
TIME 3.959083;
CREATE Plane1 Type1;
PLACE Plane1 ON GaCVM2R21R;
MOVE Plane1 GaCVM2R21R 230.000000;
TIME 40.431462;
CREATE Plane2 Type0;
PLACE Plane2 ON GaCY2R22L;
MOVE Plane2 GaCY2R22L 115.000000;
TIME 72.516855;
CREATE Plane3 Type1;
PLACE Plane3 ON GaCVM2R21R;
MOVE Plane3 GaCVM2R21R 230.000000;
TIME 100.374411;
CREATE Plane4 Type2;
PLACE Plane4 ON GaCVM2R21R;
MOVE Plane4 GaCVM2R21R 230.000000;
TIME 155.431462;
MOVE Plane2 ONRun22L 17.000000;
TIME 172.431462;
MOVE Plane2 RollingR22L 43.630666;
TIME 216.062128;
MOVE Plane2 TakeOffR22L 51.135316;
TIME 233.959083;
MOVE Plane1 ONRun21R 15.000000;
TIME 248.959083;
MOVE Plane1 RollingR21R 39.771558;
TIME 267.197444;
DESTROY Plane2;
```

Thus, the trace file required to visualize the modeled operations is constituted by all the time-ordered sequence of animation statements written out by all the activities in the model during a simulation run. The size of the generated trace files depends on the amount of detail modeled and

length of simulation. The statements in a trace file are then processed sequentially to visualize the airport modeled operations in 3D. This is accomplished using 3D CAD models of the planes and other model entities.

6.3.5 Animation Snapshots of Visualized Operations at DTW

Once the statements are processed, the result is a pictorial representation of the actual operations being conducted in a 3D virtual environment. All VITASCOPE characteristics can be of great use here. The animation can be replayed at varying speeds but in our case the animation is set to a speed of 40 (*VIEWRATIO 40).* The user can jump to any desired time and check what is happening and he can also navigate easily in the 3D virtual space. Figures 9, 10, 11 and 12 present VITASCOPE animation snapshots of the operations on the airport.

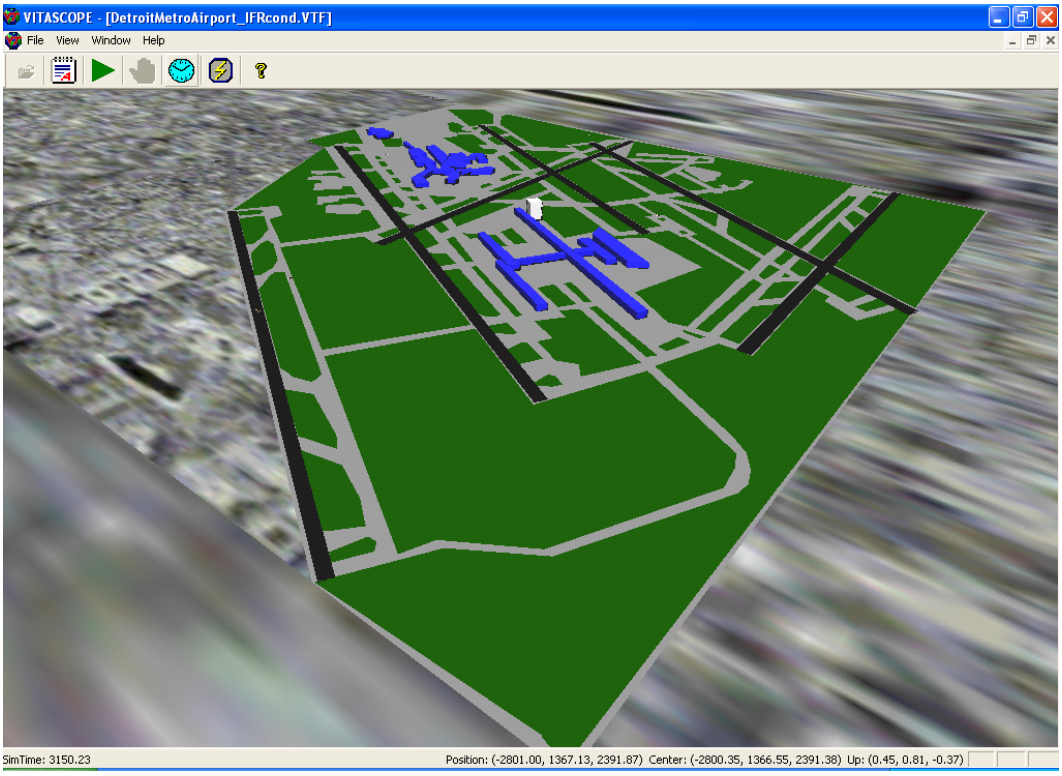


Figure 9 Bird's Eye View of Detroit Metro Airport

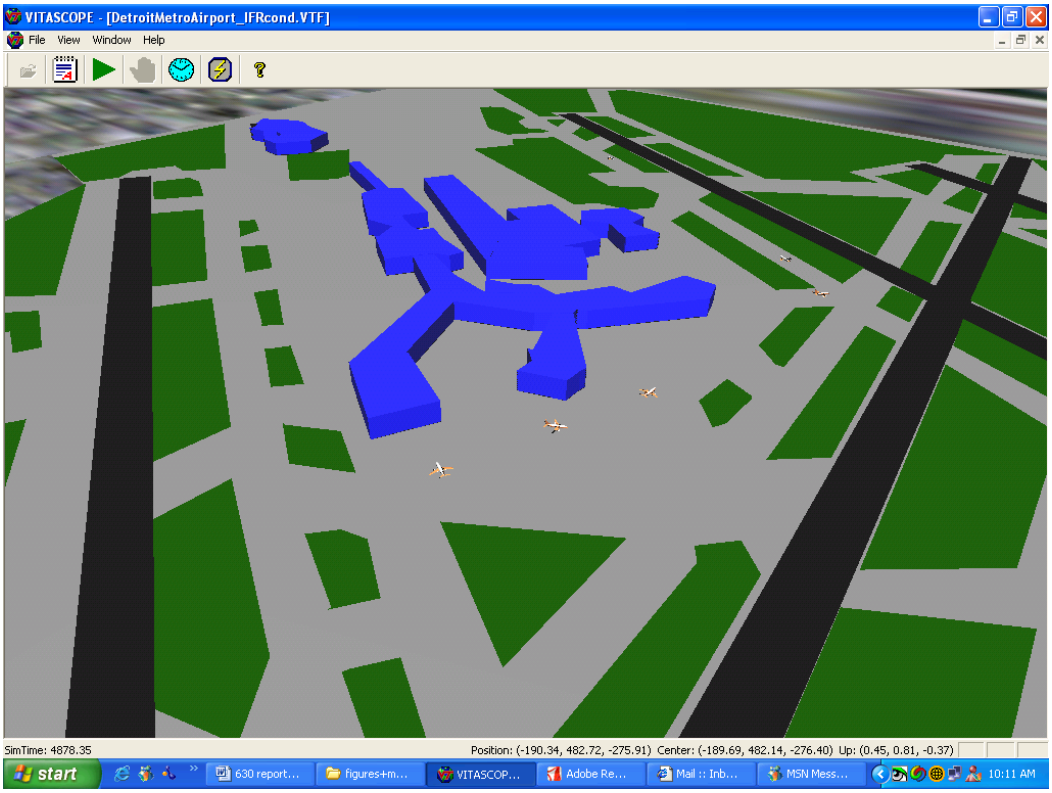


Figure 10 View of Airport Operations Around Concourse C of Smith Terminal

The following figures (11 and 12) represent two different situations on Runway 21R. In the first one, an airplane is crossing the runway while another one is departing from the same runway. This case is wrong because no two airplanes are allowed to be on the same runway. Thus this situation was rectified by including semaphores for runway crossing and rolling procedures on runway 21 R in the code. This is reflected through figure 12 where the airplane is waiting for another plane to take off before crossing and taxiing to the gate.



Figure 11 View of Airport Operations on Runway 21R (Situation 1)



Figure 12 View of Airport Operations on Runway 21R (Situation 2)

Chapter 7

DTW AIRPORT SIMULATION RESULTS

7.1 VARIABLES AND COLLECTORS

Variables and collectors were used to display all the necessary results. Collectors are action targets that keep statistics about the number they receive. This was achieved in the model by first defining the variables and collectors and then collecting the results as follows:

```
/Arrivals
COLLECT ArvPerHr  ArvsPerHr;
COLLECT ArvMxWt   ArvMaxWt;
COLLECT ArvAvWt   ArvAveWt;
/Departures
COLLECT DptPerHr  DptsPerHr;
COLLECT DptMxWt   DptMaxWt;
COLLECT DptAvWt   DptAveWt;
```

7.2 ASSUMPTIONS

The model does not include holding delays at the gate in calculating the total outbound delay. L.C Smith Terminal was the only terminal considered in this study and in particular concourse C with its different gates. Aircraft will taxi out and in from this concourse. Figure 10 shows Smith terminal and highlights the concourse in question.

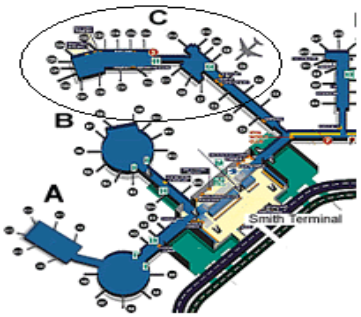


Figure 13 Smith Terminal at DTW
[Source :http://www.gofox.com/flights/airportmaps.php?code=DTW]

The model thus assumes oversimplified taxi and gate operations, i.e. all arriving planes taxi to the same concourse C before they are destroyed. Similarly, departing planes all start from the same concourse C and taxi to the appropriate designated departure runway. The taxi times assumed for all the operations are calculated based on a speed of 11m/s.

If waiting times are excessive, it is necessary to either reduce the traffic at the airport or to improve the utilization of the runway. One way to improve the use of the runway (or runways) is with the deployment of better surveillance technology that enables air traffic controllers to reduce the safety buffer added to the minimum prescribed separation between aircraft.

7.3 RUNWAY PERFORMANCE

7.3.1 Scenario I

A run of the model with ten batch means replications, each one-day in length, yielded the results below, which are taken directly from the output. The columns indicate, for each day and for both arrivals and departures, the average number of arrivals per hour, the maximum waiting time, and the average waiting time.

	------Daily Arrival Values----------			-----Daily Departure Values-----		
	Av Arvs/hr	Max Wait	Ave Wait	Av Depts/hr	Max Wait	Ave Wait
	9.79	11.19	2.11	8.46	5.19	0.55
	10.58	15.68	2.36	8	5.89	0.73
	10.42	20.24	3.99	8.83	6.2	0.83
	10.29	14.16	2.62	8.46	5.85	0.81
	9.96	14.04	2.28	9.63	10.96	0.85
	9.38	14.49	2.19	8.88	8.52	0.61
	10.21	10.09	2.08	7.04	3.92	0.68
	9.88	7.53	1.24	9.04	8.32	0.73
	9.71	10.52	1.75	7.88	4.59	0.62
	9.33	12.11	2.24	8.58	8.33	0.73
Mean	9.95	13.01	2.28	8.48	6.79	0.71
SD	0.42	3.54	0.71	0.71	2.18	0.1

These results indicate that the average daily waiting time for arriving and departing airplanes over the 10 days simulated in December 2004 was about 2.28 minutes and about 0.71 minutes respectively (Figure 14). The maximum waiting times average about 13 minutes for arrivals and 7 minutes for departures. The runway configuration assumed for the above simulation run is the one performing under IFR conditions; Arrivals on Runway 21L and 22R, and Departures on Runways 21R and 22L.

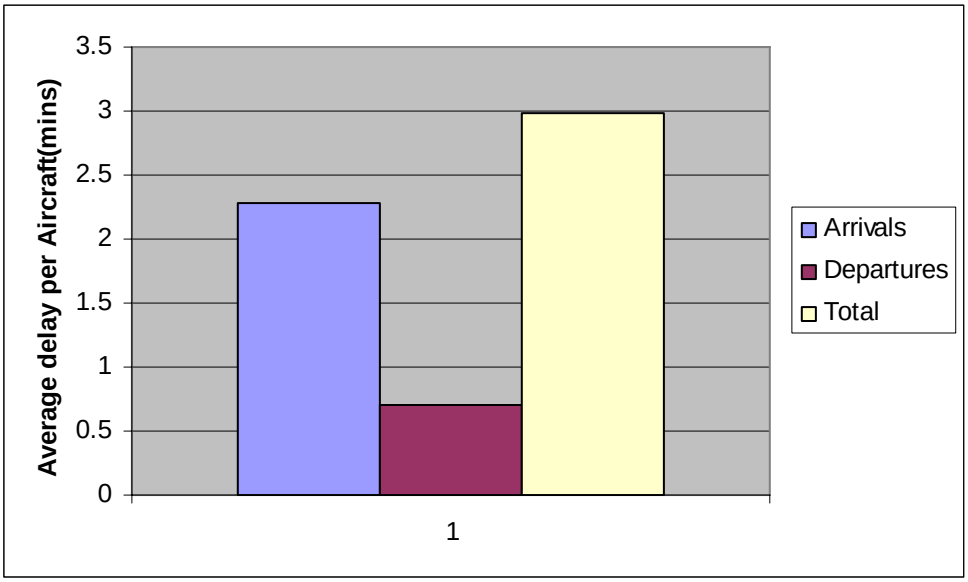


Figure 14 Delays for scenario I

7.3.2 Scenario II

	------Daily Arrival Values----------			-----Daily Departure Values-----		
	Av Arvs/hr	Max Wait	Ave Wait	Av Depts/hr	Max Wait	Ave Wait
	9.79	6.2	1.04	8.46	1.81	0.17
	10.58	9.62	1.04	8	1.79	0.29
	10.42	8.76	1.14	8.83	1.8	0.25
	10.29	7.65	0.96	8.46	1.78	0.25
	9.96	7.68	0.86	9.63	1.8	0.3
	9.38	7.1	0.92	8.88	1.8	0.27
	10.21	5.87	0.78	7.04	1.82	0.22
	9.88	6.52	0.68	9.04	1.81	0.27
	9.71	7.56	0.73	7.88	1.81	0.22
	9.33	8.36	0.89	8.58	1.78	0.19
Mean	9.95	7.53	0.9	8.48	1.8	0.24
SD	0.42	1.17	0.15	0.71	0.01	0.04

These results indicate that the average daily waiting time for arriving and departing airplanes over the 10 days simulated in December 2004 was about 0.9 minutes and about 0.24 minutes respectively (Figure 15). The maximum waiting times average about 8 minutes for arrivals and 2 minutes for departures. The runway configuration assumed for the above simulation run is the one performing under VFR conditions; Arrivals on Runway 21L, 22L and 22R, and Departures on Runways 21R and 22L for any airplane.

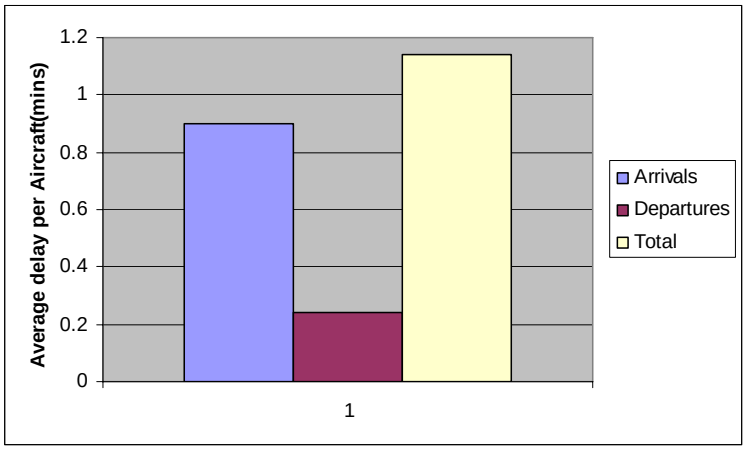


Figure 15 Delays for Scenario II

7.3.3 Scenario III

	------Daily Arrival Values----------			-----Daily Departure Values-----		
	Av Arvs/hr	Max Wait	Ave Wait	Av Depts/hr	Max Wait	Ave Wait
	10.42	8.18	1.1	8.38	1.81	0.19
	10.75	16.55	1.72	6.88	1.81	0.26
	9.13	11.59	1.08	8.25	1.81	0.29
	8.92	8.12	0.78	8.5	1.82	0.18
	10.25	9.89	0.95	8.29	1.81	0.26
	9.54	7.69	0.98	8.25	1.81	0.29
	10.25	8.19	0.96	8.21	1.78	0.16
	10.13	7.17	0.81	8.46	1.79	0.25
	10.08	9.73	0.85	8.13	1.8	0.21
	9.13	10.49	1.08	8.67	1.82	0.27
Mean	9.86	9.76	1.03	8.20	1.81	0.24
SD	0.63	2.76	0.27	0.49	0.01	0.05

These results indicate that the average daily waiting time for arriving and departing airplanes over the 10 days simulated in December 2004 was about 1 minute and about 0.24 minutes respectively (Figure 16). The maximum waiting times average about 10 minutes for arrivals and 1.81 minutes for departures. The runway configuration assumed for the above simulation run is the one performing under VFR conditions; Arrivals of heavy airplanes on Runway 22L and medium and light on 21L and 22R, and Departures on Runways 21R and 22L for any airplane.

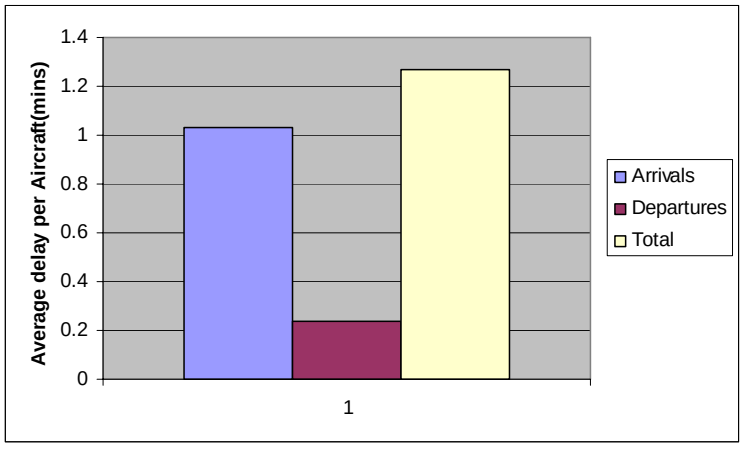


Figure 16 Delays for Scenario III

Chapter 8
CONCLUSION

In the course of this study, I have examined the previous work on airports simulation and animation. I then described airports performance in general and went into examining Detroit Metropolitan Airport specifically. Three scenarios based on different meteorological conditions were examined. By consequence, respective STROBOSCOPE models, in which all required parameters were included, were presented. Then VITASCOPE was used as 3D animation tool to ensure the credibility and validation of the models. At the end, results generated from STROBOSCOPE models were analyzed and illustrated by graphical charts.

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APPENDIX A

Aircraft Classifications

A.1 Geometric Design Classification (FAA in US)

Design Group	Wingspan (ft)	Example Aircraft
I	<49	Cessna 152-210, Beechcraft A36
II	49-78	Saab 2000, EMB-120, Saab 340, Canadair RJ-100
III	79-117	Boeing 737, MD-80, Airbus A-320
IV	118-170	Boeing 757, Boeing 767, Airbus A-300
V	171-213	Boeing 747, Boeing 777, MD-11, Airbus A-340
VI	214-262	A3XX-200 or VLCA (planned)

A.2 ATC Operational Classification (US)

Design Group	Approach Speed (knots)	Example Aircraft
A	<91	All single engine aircraft, Beechcraft,Baron 58,
B	91-120	Business jets and commuter aircraft (Beech 1900, Saab 2000, Saab 340,Embraer 120, Canadair RJ, etc.)
C	121-140	Medium and Short Range Transports(Boeing 727, B737, MD-80, A320,F100, B757, etc.)
D	141-165	Heavy transports(Boeing 747, L-1011, MD-11, DC-10,A340, A300)
E	>166	BAC Concorde and military aircraft

A.3 Wake Vortex Aircraft Classification

Group	Takeoff Gross Weight (lb)	Example Aircraft
Small	<41,000	All single engine aircraft, light twins, most business jets and commuter aircraft
Large	41,000-255,000	Large turboprop commuters, short and medium range transport aircraft (MD-80, B737, B727, A320, F100, etc.)
Heavy	>255,000	Boeing 757, Boeing 747, Douglas DC-10, MD-11, Airbus A-300, Airbus A-300, Airbus A-340, Lockheed L-1011

APPENDIX B

Instrumented Airport Simulation Model

This appendix presents the STROBOSCOPE source code for the simulated airport operation at DTW (scenario I). Since the concept behind all scenarios is almost the same, only scenario I will be included in this appendix. The respective model has been instrumented to generate a VITASCOPE animation trace file during a simulation run.

```
DISPLAY “Hiam Khoury, AIRSIDE AIRPORT OPERATIONS AT METRO DETROIT AIRPORT ";

/*************************************************************************
***************
VARIABLE RotateAttach 0;

VARIABLE Animation 1;

IF Animation;

      OUTFILE VTF "..\DetroitMetroAirport_IFRcond.VTF";
ENDIF;

/*************************************************************************
**************
/ General Section for problem parameters


SAVEVALUE nReplications* 10;
STREAMS 6;
ARRAY Seeds 10 {1618550813 346237463 546846573 797645342
                457689357 673412324 103529384 874653423 475920192 457426784};

/*************************************************************************
/ARRIVALS and Departures
/*************************************************************************
***********

IF Animation;
      VARIABLE DaysToSimulate 1;
      VARIABLE SimBeginHour 14;
ELSE;

      VARIABLE DaysToSimulate 10;
      VARIABLE SimBeginHour 6;

ENDIF;
```

```
/Define variables and matrices

VARIABLE BufferDist 2100 ;
VARIABLE ComAppL 15000;

VARIABLE ArvDptDist 3200;
VARIABLE BuffDistsd 1260;

VARIABLE MaxBufferd 2100+BuffDistsd*2;

VARIABLE MinBufferd 2100-BuffDistsd*2;


VARIABLE PlTypeNum 3;
/The following numbers are in meters(min dist sep)
ARRAY MatrixIJ PlTypeNum PlTypeNum

{     6000  6840  8760
      9000  6000    8120
      12000 9000  6000

};


/The following numbers are in seconds (min time btw successive departures)

ARRAY SepSuccDpt PlTypeNum PlTypeNum

{     60  90  120

      60  60  90

      60  60  60

};



/Define resources

/ Resource plane is characterized
CHARTYPE Plane Type AppSpeed LandingROTm LandingROTsd ToffROTm ToffROTsd x y;

SUBTYPE Plane Heavy   0  75     55            6         38       4   -25  12;

SUBTYPE Plane Medium  1  68     50            10        43       6 -13.5 6.5;

SUBTYPE Plane Light   2  52     45            10       50        6  -18   9;

SAVEPROPS Plane Nexttype  MinLeadTime LandRun;



/Resource sequencer is generic
GENTYPE Sequencer;
```

```
/ Resource arrival schedulers is characterized
CHARTYPE ArvSchdlr     StartHr  EndHr  i                ;
SUBTYPE  ArvSchdlr A     0        1    0.254;
SUBTYPE  ArvSchdlr B      1       2    0;
SUBTYPE  ArvSchdlr C      2       3    0  ;
SUBTYPE  ArvSchdlr D      3       4    0 ;
SUBTYPE  ArvSchdlr E      4       5     0  ;
SUBTYPE  ArvSchdlr F      5       6     0.153  ;
SUBTYPE  ArvSchdlr G      6       7    0 ;
SUBTYPE  ArvSchdlr H      7       8    0.095;
SUBTYPE  ArvSchdlr I      8       9    0.055 ;
SUBTYPE  ArvSchdlr J      9      10    0.041;
SUBTYPE  ArvSchdlr K     10      11    0.045;
SUBTYPE  ArvSchdlr L     11      12   0.03 ;
SUBTYPE  ArvSchdlr M     12      13   0.033;
SUBTYPE  ArvSchdlr N     13      14   0.154;
SUBTYPE  ArvSchdlr O     14      15   0.028;
SUBTYPE  ArvSchdlr P     15      16   0.038;
SUBTYPE  ArvSchdlr Q     16      17   0.033;
SUBTYPE  ArvSchdlr R     17      18   0.048;
SUBTYPE  ArvSchdlr S     18      19   0.034;
SUBTYPE  ArvSchdlr T     19      20   0.043;
SUBTYPE  ArvSchdlr U     20      21   0.031;
SUBTYPE  ArvSchdlr V    21       22   0.058;
SUBTYPE  ArvSchdlr W     22      23   0.118;
SUBTYPE  ArvSchdlr X     23      24    0.165;

SUBTYPE ArvSchdlr a     0        1       0 ;
SUBTYPE  ArvSchdlr b    1        2        0;
SUBTYPE ArvSchdlr c     2        3        0;
SUBTYPE  ArvSchdlr d    3        4        0;
SUBTYPE ArvSchdlr e     4        5        0;
SUBTYPE  ArvSchdlr f    5        6        0.5;
SUBTYPE  ArvSchdlr g    6        7        0.086;
SUBTYPE  ArvSchdlr h    7        8        0.048;
SUBTYPE  ArvSchdlr i    8        9        0.053;
SUBTYPE  ArvSchdlr j    9       10        0.033;
SUBTYPE  ArvSchdlr k    10      11        0.032;
SUBTYPE ArvSchdlr l     11      12        0.124;
SUBTYPE  ArvSchdlr m    12      13        0.026;
SUBTYPE  ArvSchdlr n    13      14        0.028;
SUBTYPE  ArvSchdlr o    14      15        0.103;
SUBTYPE  ArvSchdlr p    15      16        0.026;
SUBTYPE  ArvSchdlr q    16      17        0.097;
SUBTYPE  ArvSchdlr r    17      18        0.023;
SUBTYPE  ArvSchdlr s    18      19        0.117;
SUBTYPE  ArvSchdlr t    19      20        0.023;
SUBTYPE  ArvSchdlr u    20      21        0.194;
SUBTYPE  ArvSchdlr v    21      22        0.04;
SUBTYPE  ArvSchdlr w    22      23        0.126 ;
SUBTYPE  ArvSchdlr x    23     24         0;

SAVEPROPS  ArvSchdlr SampledIAT ;
```

```
/*********************ARRIVALS************************

/Define Queues

QUEUE ArvlSchdlrs  ArvSchdlr;
QUEUE PlanesWaitL  Plane;

QUEUE AppR22R  Plane;
QUEUE AppR21L  Plane;

QUEUE AppSignals Sequencer;
QUEUE AppSignalsa Sequencer;

QUEUE LanPl1  Plane;
QUEUE LanPl  Plane;

QUEUE PlTaxi2gate Plane;
QUEUE PlTa2gate Plane;
QUEUE Wt2CrossR21R Plane;
QUEUE Wt2CrossR22L Plane;

QUEUE WtToEnterPP Plane;
QUEUE ToWT5PP2R21R Plane;

QUEUE WtToEnterA6 Plane;
QUEUE ToA62Run22L Plane;


/*********************DEPARTURES**********************

/Define Queues

QUEUE DptSchdlrs  ArvSchdlr;
QUEUE PlanesWaitD  Plane;

QUEUE Wt2DptR22L Plane;
QUEUE Rdy2RollR22L Plane;
QUEUE Wt2DptR21R Plane;
QUEUE Rdy2RollR21R Plane;


/*********************ARRIVALS************************

/Define Combis

COMBI PArrival;

COMBI AppRwys;

COMBI PAppRun; / entry of airplane into common approach path while
approaching R21L
COMBI PAppRuna; / entry of airplane into common approach path while
approaching R22R


COMBI PLand2;
```

```
COMBI PLandb;

COMBI Plbegin2Taxi;
COMBI Plstart2Taxi;


COMBI PPF2Run21R;
COMBI WT5PPF2Run21R;

COMBI A6V2Run22L1;
COMBI A6V2Run22L2;

COMBI R21RF2Gatec;
COMBI R22LV2Gatec;

/**********************DEPARTURES**********************

/Define Combis

COMBI PDeparture;
COMBI TaxiOut2Run;

COMBI ONRun22L;
COMBI RollingR22L;


COMBI ONRun21R;
COMBI RollingR21R;
/**********************ARRIVALS************************

/Define Normals
/Run21L
NORMAL FirstSCAP;/airplane traversing first 11,800 m of common approach path
NORMAL LastSCAP;/ airplane traversing last 3200 m

/Run 22R
NORMAL FirstSCAPa;/airplane traversing first 11,800 m of common approach path
NORMAL LastSCAPa;/ airplane traversing last 3200 m


NORMAL PAppSep ;/activity accounting for separation time btw 2 succ planes
NORMAL PAppSepa ;/activity accounting for separation time btw 2 succ planes
while approaching 22R

NORMAL PLanda;
NORMAL PLand1 ;

NORMAL TaW2WJ;
NORMAL TaW1W;

NORMAL TaA42A6 ;
NORMAL TaA12A6 ;

/**********************DEPARTURES**********************
/Define Normals
NORMAL GaCY2R22L;
```

```
NORMAL TakeOffR22L;

NORMAL GaCVM2R21R;

NORMAL TakeOffR21R;

/*********************ARRIVALS************************
/Define forks
FORK TaxiOrRoll Plane;
FORK W1orW2 Plane;

FORK TaOrRo Plane;
FORK  A4orA1 Plane;
/*********************DEPARTURES**********************
/Define forks
FORK WestorEast Plane;
FORK Run22Ror21L Plane;


/*********************ARRIVALS************************
/Define links
LINK AS1 ArvlSchdlrs   PArrival;
LINK AS2 PArrival      ArvlSchdlrs;

LINK AP1 PArrival  PlanesWaitL;
LINK AP2 PlanesWaitL  AppRwys;
LINK AP3 AppRwys  Run22Ror21L ;
LINK AP4 Run22Ror21L AppR21L ;
LINK AP5 AppR21L PAppRun ;
LINK AP6 PAppRun FirstSCAP Plane;
LINK AP7 FirstSCAP LastSCAP Plane;
LINK AP8 LastSCAP PLand1 Plane;
LINK AP9 PLand1 TaxiOrRoll ;
LINK AP10 TaxiOrRoll LanPl1;
LINK AP11 TaxiOrRoll PlTaxi2gate;
LINK AP12 LanPl1 PLand2;
LINK AP13 PLand2 PlTaxi2gate;
LINK AP14 PlTaxi2gate Plbegin2Taxi  ;
LINK AP15 Plbegin2Taxi W1orW2;
LINK AP16 W1orW2 TaW2WJ;
LINK AP17 W1orW2 TaW1W ;
LINK AP18 TaW2WJ WtToEnterPP;
LINK AP19 WtToEnterPP PPF2Run21R;
LINK AP20 PPF2Run21R Wt2CrossR21R;
LINK AP42 TaW1W ToWT5PP2R21R;
LINK AP43 ToWT5PP2R21R WT5PPF2Run21R ;
LINK AP44  WT5PPF2Run21R Wt2CrossR21R;
LINK AP45 Wt2CrossR21R R21RF2Gatec;



LINK AP21 Run22Ror21L AppR22R;
LINK AP22 AppR22R PAppRuna;
LINK AP23 PAppRuna  FirstSCAPa Plane;
LINK AP24 FirstSCAPa  LastSCAPa Plane;
LINK AP25 LastSCAPa  PLanda Plane;
LINK AP26 PLanda TaOrRo;
```

```
LINK AP27 TaOrRo LanPl;
LINK AP28 TaOrRo PlTa2gate;
LINK AP29 LanPl PLandb;
LINK AP30 PLandb PlTa2gate;
LINK AP31 PlTa2gate Plstart2Taxi  ;
LINK AP32 Plstart2Taxi A4orA1;
LINK AP33 A4orA1 TaA42A6;
LINK AP34 A4orA1 TaA12A6;
LINK AP35 TaA42A6 WtToEnterA6;
LINK AP36 WtToEnterA6 A6V2Run22L1;
LINK AP37 A6V2Run22L1 Wt2CrossR22L;
LINK AP38 TaA12A6 ToA62Run22L;
LINK AP39 ToA62Run22L A6V2Run22L2;
LINK AP40 A6V2Run22L2 Wt2CrossR22L;
LINK AP41 Wt2CrossR22L R22LV2Gatec ;

LINK SE1 PAppRun PAppSep Sequencer;
LINK SE2 PAppSep AppSignals;
LINK SE3 AppSignals PAppRun;

LINK SE4 PAppRuna PAppSepa Sequencer;
LINK SE5 PAppSepa AppSignalsa;
LINK SE6 AppSignalsa PAppRuna;

/**********************DEPARTURES**********************
/Define links
LINK DS1 DptSchdlrs    PDeparture;
LINK DS2 PDeparture   DptSchdlrs;

LINK DP1 PDeparture  PlanesWaitD;
LINK DP2 PlanesWaitD  TaxiOut2Run;
LINK DP3 TaxiOut2Run  WestorEast;

LINK DP4 WestorEast   GaCY2R22L;
LINK DP5 WestorEast   GaCVM2R21R;
LINK DP6 GaCY2R22L  Wt2DptR22L;
LINK DP7 Wt2DptR22L   ONRun22L;
LINK DP8 ONRun22L    Rdy2RollR22L;
LINK DP9 Rdy2RollR22L RollingR22L;
LINK DP10 RollingR22L TakeOffR22L  Plane;

LINK DP11 GaCVM2R21R   Wt2DptR21R;
LINK DP12 Wt2DptR21R   ONRun21R;
LINK DP13 ONRun21R    Rdy2RollR21R;
LINK DP14 Rdy2RollR21R RollingR21R;
LINK DP15 RollingR21R TakeOffR21R  Plane;


/**********************ARRIVALS***********************

VARIABLE CurHour Mod[SimTime/3600+SimBeginHour,24];

VARPROP ArvSchdlr NextArv 'SampledIAT+CurHour*3600<EndHr*3600 ? SampledIAT :

                           SampledIAT+(24-(EndHr-StartHr))*3600';
```

```
/Define the next arrival type and initialize its value, one third of planes
is of a particular type(equal probability)
VARIABLE NextArvType 'sRnd[1]<=1/3 ? Heavy   : sLastRnd [1]<=2/3 ? Medium:
Light' ;



/ Startup of Parrival activity

ONDRAW AS1 ASSIGN SampledIAT PRECOND 'i!=0' sExponential[i*3600,1];

ONDRAW AS1 ASSIGN SampledIAT PRECOND 'i==0' 24*60*60;


ONDRAW AS1 ASSIGN SampledIAT PRECOND '!SimTime & i!=0'

                  SampledIAT+Mod[StartHr-SimBeginHour+24,24]*3600;


DURATION PArrival 'PArrival.ArvSchdlr.i==0?PArrival.ArvSchdlr.SampledIAT:
PArrival.ArvSchdlr.NextArv';



/Generate the arriving plane based on its type
BEFOREEND PArrival  GENERATE   1  NextArvType ;



ONRELEASE AP1 ASSIGN MinLeadTime

'Min[ComAppL,
(MatrixIJ[NextArvType==Heavy ? 0 : NextArvType==Medium ? 1 : 2, Type]
+ Max[MinBufferd, Min[sNormal[BufferDist,BuffDistsd,2], MaxBufferd]])]/
AppSpeed';



/ assign the arrival runway
VARIABLE R21L 1;
VARIABLE R22R 2;

ONDRAW AP2 ASSIGN LandRun 'sRnd[1]<=0.5?R21L:R22R' ;


/Startup of approaching runways activities

COLLECTOR ArvWaits;
ONDRAW AP5 COLLECT ArvWaits SimTime-TimeIn;
ONDRAW AP22 COLLECT ArvWaits SimTime-TimeIn;


DURATION AppRwys  ' 0';
DURATION PAppRun  ' 0';
DURATION PAppRuna  ' 0';
```

```
STRENGTH AP4 ' AppRwys.Plane.LandRun==R21L' ;
STRENGTH AP21 'AppRwys.Plane.LandRun==R22R' ;



/Startup of approach separation activity

DURATION  PAppSep 'FirstSCAP.Plane.MinLeadTime' ;
DURATION  PAppSepa 'FirstSCAPa.Plane.MinLeadTime' ;


/Startup of common approach path activities

DURATION  FirstSCAP ' (ComAppL-ArvDptDist)/ (FirstSCAP.Plane.AppSpeed)';
DURATION  LastSCAP ' ArvDptDist/ (LastSCAP.Plane.AppSpeed)';
DURATION  FirstSCAPa ' (ComAppL-ArvDptDist)/ (FirstSCAPa.Plane.AppSpeed)';
DURATION  LastSCAPa ' ArvDptDist/ (LastSCAPa.Plane.AppSpeed)';


/Startup of landing activities

DURATION  PLand1  ' 1586/(0.9*PLand1.Plane.AppSpeed)';
/FORK Taxi or Roll
STRENGTH AP10  ' (PLand1.Plane.Type==0) ? 1: 0' ;/ type 0 refer to heavy
STRENGTH AP11  ' ((PLand1.Plane.Type!=0)) ? 1: 0' ; /in this case its either
type 1 or 2 (medium or light)



DURATION  PLand2  ' 1170/(0.5*PLand2.Plane.AppSpeed)';


DURATION  PLanda  '1832/(0.9*PLanda.Plane.AppSpeed)';
/fork Ta or Ro
STRENGTH AP28  ' ((PLanda.Plane.Type!=0)) ? 1: 0' ; /in this case its either
type 1 or 2 (medium or light)
STRENGTH AP27  ' (PLanda.Plane.Type==0) ? 1: 0' ;/ type 0 refer to heavy



DURATION  PLandb  '1016/(0.5*PLandb.Plane.AppSpeed)';



/Startup of taxiing activities;
/***********************************
/Arrival on Run21L
DURATION Plbegin2Taxi '0';
/fork W1 or W2
STRENGTH AP16  ' ((Plbegin2Taxi.Plane.Type!=0)) ? 1: 0' ; /in this case its
either type 1 or 2 (medium or light)
STRENGTH AP17  ' (Plbegin2Taxi.Plane.Type==0) ? 1: 0' ;/ type 0 refer to
heavy
```

```
DURATION TaW2WJ '83';
SEMAPHORE PPF2Run21R '!WT5PPF2Run21R.CurInst & !Wt2CrossR21R.CurCount' ;
DURATION PPF2Run21R '130';


DURATION TaW1W '20';
SEMAPHORE WT5PPF2Run21R '!PPF2Run21R.CurInst &!TaW2WJ.CurInst &
!Wt2CrossR21R.CurCount';
DURATION WT5PPF2Run21R '154';

SEMAPHORE R21RF2Gatec '!RollingR21R.CurInst & !TakeOffR21R.CurInst&
!R21RF2Gatec.CurInst' ;
DURATION R21RF2Gatec '109';
/***********************************

/Arrival on Run22R
DURATION Plstart2Taxi '0';
/fork A4 or A1
STRENGTH AP33  ' ((Plstart2Taxi.Plane.Type!=0)) ? 1: 0' ; /in this case its
either type 1 or 2 (medium or light)
STRENGTH AP34  ' (Plstart2Taxi.Plane.Type==0) ? 1: 0' ;/ type 0 refer to
heavy



SEMAPHORE A6V2Run22L1 '!TaA12A6.CurInst' ;
DURATION TaA42A6 '30';
DURATION A6V2Run22L1 '270';


DURATION TaA12A6 '20';
DURATION A6V2Run22L2 '350';

SEMAPHORE R22LV2Gatec '!RollingR22L.CurInst&!Rdy2RollR22L.CurCount&
!ONRun22L.CurInst & !R22LV2Gatec.CurInst' ;
DURATION R22LV2Gatec '32';



/**********************DEPARTURES**********************

/Define the next departure type and initialize its value, one third of planes
is of a particular type(equal probability)
VARIABLE NextDptType 'sRnd[1]<=1/3 ? Heavy   : sLastRnd [1]<=2/3 ? Medium:
Light' ;

/ Startup of PDeparture activity


ONDRAW DS1 ASSIGN SampledIAT PRECOND 'i!=0' sExponential[(i)*3600,1];
ONDRAW DS1 ASSIGN SampledIAT PRECOND 'i==0' DaysToSimulate*24*60*60;
ONDRAW DS1 ASSIGN SampledIAT PRECOND '!SimTime & i!=0'
SampledIAT+Mod[StartHr-SimBeginHour+24,24]*3600;

DURATION PDeparture
'PDeparture.ArvSchdlr.i==0?PDeparture.ArvSchdlr.SampledIAT:
PDeparture.ArvSchdlr.NextArv';
```

```
/Generate the departing plane based on its type
BEFOREEND PDeparture  GENERATE   1  NextDptType ;


/Define savevalues

SAVEVALUE LeadingPlTypeR22L -1 ;
SAVEVALUE LeadingPlTypeR21R -1 ;


/Startup of TaxiOut2Run activity
SEMAPHORE TaxiOut2Run '!TaxiOut2Run.CurInst';
DURATION TaxiOut2Run  ' 0 ';
STRENGTH DP4  '(TaxiOut2Run.Plane.Type==0)?1: 0' ;/ type 0 refer to heavy
STRENGTH DP5  ' ((TaxiOut2Run.Plane.Type!=0)) ?1: 0' ; /in this case its
either type 1 or 2 (medium or light)



/Startup of departing activities

/Departure on R 22L
DURATION GaCY2R22L  '115';

SEMAPHORE ONRun22L '!ONRun22L.CurInst & !RollingR22L.CurInst &
!Rdy2RollR22L.CurCount' ;
DURATION  ONRun22L '17'   ;/(100/6)


COLLECTOR DptWaits;
ONDRAW DP9 COLLECT DptWaits 'SimTime-TimeIn';

PRIORITY RollingR22L 10;
SEMAPHORE RollingR22L '!R22LV2Gatec.CurInst&!TakeOffR22L.CurInst' ;
DURATION  RollingR22L 'sNormal[(RollingR22L.Plane.ToffROTm
),RollingR22L.Plane.ToffROTsd,3]';


DURATION TakeOffR22L 'Max[0,LeadingPlTypeR22L==-1 ? 0 :

SepSuccDpt[TakeOffR22L.Plane.Type,LeadingPlTypeR22L]-
sNormal[TakeOffR22L.Plane.ToffROTm,TakeOffR22L.Plane.ToffROTsd,3]]';

ONSTART TakeOffR22L  ASSIGN LeadingPlTypeR22L TakeOffR22L.Plane.Type;


/Departure on R 21R
DURATION  GaCVM2R21R  '230';

SEMAPHORE ONRun21R '!ONRun21R.CurInst & !RollingR21R.CurInst &
!Rdy2RollR21R.CurCount' ;
DURATION  ONRun21R '15';/(90/6)
ONDRAW DP14 COLLECT DptWaits 'SimTime-TimeIn';
```

```
PRIORITY RollingR21R 10;
SEMAPHORE RollingR21R '!LastSCAP.CurInst&!PLand1.CurInst &
!R21RF2Gatec.CurInst&!TakeOffR21R.CurInst' ;
DURATION  RollingR21R
'sNormal[RollingR21R.Plane.ToffROTm,RollingR21R.Plane.ToffROTsd,3]';


DURATION TakeOffR21R 'Max[0,LeadingPlTypeR21R==-1 ? 0 :

SepSuccDpt[TakeOffR21R.Plane.Type,LeadingPlTypeR21R]-
sNormal[TakeOffR21R.Plane.ToffROTm,TakeOffR21R.Plane.ToffROTsd,3]]';

ONSTART TakeOffR21R  ASSIGN LeadingPlTypeR21R TakeOffR21R.Plane.Type;


/*************************************************************

IF Animation;

PRINT VTF
"PATH AlignPath1
      '(12477.7,1500,-11003.30)'
      '(12477.648,1500,-11003.330)'\059


NONDIRECPATH FirstSCAP
'(12477.648,1500,-11003.330)'
'(3406.164,316,-3375.419)'\059

NONDIRECPATH LastSCAP
'(3406.164.471,316,-3375.419)'
'(1726.8,0,-408.643)'\059

PATH PLand1
      '(1726.8,0,-408.643)'
      '(1034.906,0,883.118)'\059

PATH PLand2
      '(1034.906,0,883.118)'
      '(508.815.415,0,1867.593)'\059


PATH TaW2WJ
'(1034.906,0,883.118)'
'(744.419,0,965.596)'
'(555.969,0,1311.656)'
'(349.941,0,1329.344)'\059

PATH PPF2Run21R
   '(349.941,0,1329.344)'
   '(336.050,0,1322.398)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)'\059
```

```
PATH TaW1W
      '(508.815.415,0,1867.593)'
      '(290.039,0,1794.669)'
    '(299.983,0,1773.565)'\059

PATH WT5PPF2Run21R
       '(299.983,0,1773.565)'
      '(441.096,0,1523.808)'
      '(342.127,0,1430.048)'
    '(284.830,0,1419.631)'
   '(336.050,0,1329.344)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)'\059

PATH  R21RF2Gatec
'(750.133,0,263.263)'
'(579.131,0,75.744)'
'(294.380,0,-334.019)'
'(363.831,0,-406.943)'
'(186.366,0,-646.161)'
'(248.814,0,-768.153)'\059

PATH AlignPath2
      '(-6855,1500,-13073)'
      '(-6853.208,1500,-13072.443)'\059


NONDIRECPATH FirstSCAPa
'(-6853.208,1500,-13072.443)'
'(820.145,316,-4038.011)'\059


NONDIRECPATH LastSCAPa
'(820.145,316,-4038.011)'
'(-841.169,0,-1106.630)'\059


PATH PLanda
      '(-841.169,0,-1106.630)'
   '(-1673.702,0,403.903)'\059


PATH PLandb
       '(-1673.702,0,403.903)'
      '(-2135.989,0,1239.925)'\059



PATH TaA42A6
      '(-1673.702,0,403.903)'
      '(-1611.196,0,534.124)'\059
```

```
PATH A6V2Run22L1
      '(-1611.196,0,534.124)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)'\059


PATH TaA12A6
      '(-2135.989,0,1239.925)'
      '(-1991.443,0,1325.871)'\059


PATH A6V2Run22L2
'(-1991.443,0,1325.871)'
'(-1715.373,0,841.447)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)'\059



PATH R22LV2Gatec
 '(-79.790,0,-934.775)'
'(86.893,0,-893.104)'
'(165.026,0,-929.566)'
'(279.621,0,-882.686)'\059



PATH GaCY2R22L
      '(312.292,0,-919.148)'
      '(715.863,0,-1744.753)'
     '(584.903,0,-1807.295)'\059

PATH ONRun22L
      '(584.903,0,-1807.295)'
      '(481.465,0,-1869.766)'
'(442.398,0,-1776.006)'\059


PATH RollingR22L
      '(442.398,0,-1776.006)'
       '(-1122.431,0,1110.572)'\059

PATH TakeOffR22L
      '(-1122.431,0,1110.572)'
      '(-3399.300,500,5589.976)'\059
```

```
PATH GaCVM2R21R
      '(278.319,0,-760.278)'
      '(372.078,0,-596.199)'
      '(848.689,0,-564.946)'
      '(929.861,0,-497.230)'
   '(1248.469,0,-1007.699)'
      '(1458.126,0,-1440.034)'
     '(1544.072,0,-1588.487)'\059


PATH ONRun21R
      '(1544.072,0,-1588.487)'
      '(1645.645,0,-1525.981)'
'(1606.579,0,-1447.848)'\059



PATH RollingR21R
      '(1606.579,0,-1447.848)'
       '(513.152,0,582.740)'\059



PATH TakeOffR21R
      '(513.152,0,582.740)'
      '(-1765.401,500,5054.076)'\059\n";



PRINT VTF
"TIME 0\059


VIEWPOINT Overview '(-2801, 1367.13, 2391.87)'
'(-2800.35,1366.55,2391.38)' '(0.45,0.81,-0.37)';
VIEWRATIO 40;



CLASS AirSide DTW.ac\059
CREATE AirSide AirSide\059
PLACE AirSide AT (0,0,0)\059
CLASS Type0 DC10.osg\059
SET CLASS Type0 RGP 30\059
SET CLASS Type0 AFTCLEARANCE 75\059
CLASS Type1 Boeing737.osg\059
SET CLASS Type1 RGP 25\059
SET CLASS Type1 AFTCLEARANCE 60\059
CLASS Type2 Avro.osg\059
SET CLASS Type2 RGP 25\059
SET CLASS Type2 AFTCLEARANCE 60\059\n";
```

```
ONRELEASE AP1 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONRELEASE AP1 PRINT VTF
            "CREATE Plane%.0f Type%.0f\059\n"
            ResNum
            Type;


ONDRAW AP5 PRINT VTF
            "TIME %f\059\n" RelTime;
ONDRAW AP5 PRINT VTF
            "PLACE Plane%.0f ON AlignPath1\059\n"
            ResNum;

ONSTART FirstSCAP PRINT VTF
            "TIME %f\059\n" RelTime;
ONSTART FirstSCAP PRINT VTF
            "MOVE Plane%.0f FirstSCAP %f\059\n"
            FirstSCAP.Plane.ResNum
            FirstSCAP.Duration;

ONSTART LastSCAP PRINT VTF
            "TIME %f\059\n" RelTime;
ONSTART LastSCAP PRINT VTF
            "MOVE Plane%.0f LastSCAP %f\059\n"
            LastSCAP.Plane.ResNum
            LastSCAP.Duration;

ONSTART PLand1 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART PLand1 PRINT VTF
            "MOVE Plane%.0f PLand1 %f\059\n"
            PLand1.Plane.ResNum
            PLand1.Duration;

ONSTART PLand2 PRINT VTF
            "TIME %f\059\n"
            RelTime;


ONSTART PLand2 PRINT VTF
            "MOVE Plane%.0f PLand2 %f\059\n"
            PLand2.Plane.ResNum
            PLand2.Duration;



ONSTART TaW2WJ PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TaW2WJ PRINT VTF
            "MOVE Plane%.0f TaW2WJ %f\059\n"
            TaW2WJ.Plane.ResNum
            TaW2WJ.Duration;
```

```
ONSTART PPF2Run21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART PPF2Run21R PRINT VTF
            "MOVE Plane%.0f PPF2Run21R %f\059\n"
            PPF2Run21R.Plane.ResNum
            PPF2Run21R.Duration;


ONSTART TaW1W PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TaW1W PRINT VTF
            "MOVE Plane%.0f TaW1W %f\059\n"
            TaW1W.Plane.ResNum
            TaW1W.Duration;

ONSTART WT5PPF2Run21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART WT5PPF2Run21R PRINT VTF
            "MOVE Plane%.0f WT5PPF2Run21R %f\059\n"
            WT5PPF2Run21R.Plane.ResNum
            WT5PPF2Run21R.Duration;

ONSTART R21RF2Gatec PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART R21RF2Gatec PRINT VTF
            "MOVE Plane%.0f R21RF2Gatec %f\059\n"
            R21RF2Gatec.Plane.ResNum
            R21RF2Gatec.Duration;

BEFOREEND R21RF2Gatec PRINT VTF
            "TIME %f\059\n"
            RelTime;
BEFOREEND R21RF2Gatec PRINT VTF
            "DESTROY Plane%.0f\059\n"
            R21RF2Gatec.Plane.ResNum;

/************
ONDRAW AP22 PRINT VTF
            "TIME %f\059\n" RelTime;
ONDRAW AP22 PRINT VTF
            "PLACE Plane%.0f ON AlignPath2\059\n"
            ResNum;



ONSTART FirstSCAPa PRINT VTF
            "TIME %f\059\n" RelTime;
ONSTART FirstSCAPa PRINT VTF
            "MOVE Plane%.0f FirstSCAPa %f\059\n"
            FirstSCAPa.Plane.ResNum
            FirstSCAPa.Duration;
```

```
ONSTART LastSCAPa PRINT VTF
            "TIME %f\059\n" RelTime;
ONSTART LastSCAPa PRINT VTF
            "MOVE Plane%.0f LastSCAPa %f\059\n"
            LastSCAPa.Plane.ResNum
            LastSCAPa.Duration;

ONSTART PLanda PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART PLanda PRINT VTF
            "MOVE Plane%.0f PLanda %f\059\n"
            PLanda.Plane.ResNum
            PLanda.Duration;


ONSTART PLandb PRINT VTF
            "TIME %f\059\n"
            RelTime;

ONSTART PLandb PRINT VTF
            "MOVE Plane%.0f PLandb %f\059\n"
            PLandb.Plane.ResNum
            PLandb.Duration;



ONSTART TaA42A6 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TaA42A6 PRINT VTF
            "MOVE Plane%.0f TaA42A6 %f\059\n"
            TaA42A6.Plane.ResNum
            TaA42A6.Duration;


ONSTART A6V2Run22L1 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART A6V2Run22L1 PRINT VTF
            "MOVE Plane%.0f A6V2Run22L1 %f\059\n"
            A6V2Run22L1.Plane.ResNum
            A6V2Run22L1.Duration;



ONSTART TaA12A6 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TaA12A6 PRINT VTF
            "MOVE Plane%.0f TaA12A6 %f\059\n"
            TaA12A6.Plane.ResNum
            TaA12A6.Duration;
```

```
ONSTART A6V2Run22L2 PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART A6V2Run22L2 PRINT VTF
            "MOVE Plane%.0f A6V2Run22L2 %f\059\n"
            A6V2Run22L2.Plane.ResNum
            A6V2Run22L2.Duration;

ONSTART R22LV2Gatec PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART R22LV2Gatec PRINT VTF
            "MOVE Plane%.0f R22LV2Gatec %f\059\n"
            R22LV2Gatec.Plane.ResNum
            R22LV2Gatec.Duration;

BEFOREEND R22LV2Gatec PRINT VTF
            "TIME %f\059\n"
            RelTime;
BEFOREEND R22LV2Gatec PRINT VTF
            "DESTROY Plane%.0f\059\n"
            R22LV2Gatec.Plane.ResNum;



/*******************************************


ONSTART GaCY2R22L PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART GaCY2R22L PRINT VTF
            "CREATE Plane%.0f Type%.0f\059\n"
            GaCY2R22L.Plane.ResNum
            GaCY2R22L.Plane.Type;

ONSTART GaCY2R22L PRINT VTF
            "PLACE Plane%.0f ON GaCY2R22L\059\n"
            GaCY2R22L.Plane.ResNum;
ONSTART GaCY2R22L PRINT VTF
            "MOVE Plane%.0f GaCY2R22L %f\059\n"
            GaCY2R22L.Plane.ResNum
            GaCY2R22L.Duration;



ONSTART ONRun22L PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART ONRun22L PRINT VTF
            "MOVE Plane%.0f ONRun22L %f\059\n"
            ONRun22L.Plane.ResNum
            ONRun22L.Duration;
```

```
ONSTART RollingR22L PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART RollingR22L PRINT VTF
            "MOVE Plane%.0f RollingR22L %f\059\n"
            RollingR22L.Plane.ResNum
            RollingR22L.Duration;


SAVEVALUE TORollTimeR22L 0 ;
ONDRAW DP9 ASSIGN TORollTimeR22L Normal[ToffROTm,ToffROTsd];
VARIABLE    SpaceOffTimeR22L '5025/(((3660-100-100)/TORollTimeR22L)+5)';
SAVEVALUE   PostTakeOffTimeR22L     100;
NORMAL            PostTakeOffR22L;
DURATION    PostTakeOffR22L   PostTakeOffTimeR22L;
LINK        DP16  TakeOffR22L PostTakeOffR22L   Plane;

ONSTART TakeOffR22L ASSIGN PostTakeOffTimeR22L SpaceOffTimeR22L-
TakeOffR22L.Duration;

ONSTART TakeOffR22L PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TakeOffR22L PRINT VTF
            "MOVE Plane%.0f TakeOffR22L %f\059\n"
             TakeOffR22L.Plane.ResNum
             'SpaceOffTimeR22L';


BEFOREEND PostTakeOffR22L PRINT VTF
            "TIME %f\059\n"
            RelTime;
BEFOREEND PostTakeOffR22L PRINT VTF
            "DESTROY Plane%.0f\059\n"
            PostTakeOffR22L.Plane.ResNum;

/************************************

ONSTART GaCVM2R21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART GaCVM2R21R PRINT VTF
            "CREATE Plane%.0f Type%.0f\059\n"
            GaCVM2R21R.Plane.ResNum
            GaCVM2R21R.Plane.Type;
ONSTART GaCVM2R21R PRINT VTF
            "PLACE Plane%.0f ON GaCVM2R21R\059\n"
            GaCVM2R21R.Plane.ResNum;
ONSTART GaCVM2R21R PRINT VTF
            "MOVE Plane%.0f GaCVM2R21R %f\059\n"
            GaCVM2R21R.Plane.ResNum
            GaCVM2R21R.Duration;
```

```
ONSTART ONRun21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART ONRun21R PRINT VTF
            "MOVE Plane%.0f ONRun21R %f\059\n"
            ONRun21R.Plane.ResNum
            ONRun21R.Duration;

ONSTART RollingR21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART RollingR21R PRINT VTF
            "MOVE Plane%.0f RollingR21R %f\059\n"
            RollingR21R.Plane.ResNum
            RollingR21R.Duration;


SAVEVALUE TORollTimeR21R 0 ;
ONDRAW DP14 ASSIGN TORollTimeR21R Normal[ToffROTm,ToffROTsd];
VARIABLE    SpaceOffTimeR21R  '5025/(((2590-100-100)/TORollTimeR21R)+5)';
SAVEVALUE   PostTakeOffTimeR21R     100;
NORMAL            PostTakeOffR21R;
DURATION    PostTakeOffR21R   PostTakeOffTimeR21R;
LINK        DP17  TakeOffR21R PostTakeOffR21R   Plane;

ONSTART TakeOffR21R ASSIGN PostTakeOffTimeR21R SpaceOffTimeR21R-
TakeOffR21R.Duration;

ONSTART TakeOffR21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
ONSTART TakeOffR21R PRINT VTF
            "MOVE Plane%.0f TakeOffR21R %f\059\n"
             TakeOffR21R.Plane.ResNum
             'SpaceOffTimeR21R';

BEFOREEND PostTakeOffR21R PRINT VTF
            "TIME %f\059\n"
            RelTime;
BEFOREEND PostTakeOffR21R PRINT VTF
            "DESTROY Plane%.0f\059\n"
            PostTakeOffR21R.Plane.ResNum;


IF RotateAttach;


ONSTART TaxiOut2Run PRINT VTF PRECOND 1==Attachment
      "ATTACHCAMERATO Plane%.0f (%f,%f,0)\059\n"
      TaxiOut2Run.Plane.ResNum TaxiOut2Run.Plane.x TaxiOut2Run.Plane.y;

ONSTART TaxiOut2Run ASSIGN AttachmentPlane PRECOND 1==Attachment
TaxiOut2Run.Plane.ResNum;
ONSTART TaxiOut2Run ASSIGN Attachment PRECOND 1==Attachment 2;
```

```
BEFOREEND PostTakeOffR22L PRINT VTF PRECOND
2==Attachment&AttachmentPlane==PostTakeOffR22L.Plane.ResNum
"CAMERA POSITION '(298,425,1900)'\059
CAMERA HORIZORIENT 14\059
CAMERA VERTORIENT -13.5\059
";
BEFOREEND PostTakeOffR21R PRINT VTF PRECOND
2==Attachment&AttachmentPlane==PostTakeOffR21R.Plane.ResNum
"CAMERA POSITION '(298,425,1900)'\059
CAMERA HORIZORIENT 14\059
CAMERA VERTORIENT -13.5\059
";


BEFOREEND PostTakeOffR22L ASSIGN Attachment PRECOND
2==Attachment&AttachmentPlane==PostTakeOffR22L.Plane.ResNum 3;
BEFOREEND PostTakeOffR21R ASSIGN Attachment PRECOND
2==Attachment&AttachmentPlane==PostTakeOffR21R.Plane.ResNum 3;


ONDRAW AP2 PRINT VTF PRECOND 3==Attachment
      "ATTACHCAMERATO Plane%.0f (%f,%f,0)\059\n"
      ResNum x y;

ONDRAW AP2 ASSIGN AttachmentPlane PRECOND 3==Attachment ResNum;
ONDRAW AP2 ASSIGN Attachment PRECOND 3==Attachment 4;


BEFOREEND R22LV2Gatec PRINT VTF PRECOND
4==Attachment&AttachmentPlane==R22LV2Gatec.Plane.ResNum
"CAMERA POSITION '(298,425,1900)'\059
CAMERA HORIZORIENT 14\059
CAMERA VERTORIENT -13.5\059
";
BEFOREEND R21RF2Gatec PRINT VTF PRECOND
4==Attachment&AttachmentPlane==R21RF2Gatec.Plane.ResNum
"CAMERA POSITION '(298,425,1900)'\059
CAMERA HORIZORIENT 14\059
CAMERA VERTORIENT -13.5\059
";

BEFOREEND R22LV2Gatec ASSIGN Attachment PRECOND
4==Attachment&AttachmentPlane==R22LV2Gatec.Plane.ResNum 5;
BEFOREEND R21RF2Gatec  ASSIGN Attachment PRECOND
4==Attachment&AttachmentPlane==R21RF2Gatec.Plane.ResNum 5;


COMBI NoAttach;
DURATION NoAttach NoRideTime;
SEMAPHORE NoAttach 5==Attachment;
ONSTART NoAttach ASSIGN Attachment 6;
ONEND NoAttach ASSIGN Attachment 1;

ENDIF;

ENDIF; /Animate
```

```
/*************************************************************************
****************************************
/Define some useful variables to produce the desired results
/Arrivals

VARIABLE ArvsPerHr PlanesWaitL.TotCount/SimTime*3600;
VARIABLE ArvMaxWt ArvWaits.MaxVal/60;
VARIABLE ArvAveWt ArvWaits.AveVal/60;


/Departures

VARIABLE DptsPerHr PlanesWaitD.TotCount/SimTime*3600;
VARIABLE DptMaxWt DptWaits.MaxVal/60;
VARIABLE DptAveWt DptWaits.AveVal/60;


/Define Collectors
/Arrivals

COLLECTOR ArvPerHr*;
COLLECTOR ArvMxWt*;
COLLECTOR ArvAvWt*;

/Departures

COLLECTOR DptPerHr*;
COLLECTOR DptMxWt*;
COLLECTOR DptAvWt*;


/ Headers for table results


PRINT StdOutput "------Daily Arrival Values------|-----Daily Departure
Values------\n";
PRINT StdOutput "Av Arvs/hr  Max Wait  Ave Wait |Av Depts/hr  Max Wait  Ave
Wait\n";
PRINT StdOutput
"================================|================================\n";


/*************************************************************************


/ Start the replication

WHILE nReplications;
CLEAR;
```

```
/*********************ARRIVALS************************
INIT  ArvlSchdlrs  1  A;
INIT  ArvlSchdlrs  1  B;
INIT  ArvlSchdlrs  1  C;
INIT  ArvlSchdlrs  1  D;
INIT  ArvlSchdlrs  1  E;
INIT  ArvlSchdlrs  1 F;
INIT  ArvlSchdlrs  1 G ;
INIT  ArvlSchdlrs  1 H ;
INIT  ArvlSchdlrs  1 I ;
INIT  ArvlSchdlrs  1 J ;
INIT  ArvlSchdlrs  1 K ;
INIT  ArvlSchdlrs  1 L ;
INIT  ArvlSchdlrs  1 M ;
INIT  ArvlSchdlrs  1 N ;
INIT  ArvlSchdlrs  1 O ;
INIT  ArvlSchdlrs  1 P ;
INIT  ArvlSchdlrs  1 Q ;
INIT  ArvlSchdlrs  1 R ;
INIT  ArvlSchdlrs  1 S ;
INIT  ArvlSchdlrs  1 T ;
INIT  ArvlSchdlrs  1 U ;
INIT  ArvlSchdlrs  1 V ;
INIT  ArvlSchdlrs  1 W ;
INIT  ArvlSchdlrs  1 X ;


/*********************DEPARTURES**********************
INIT  DptSchdlrs  1  a;
INIT  DptSchdlrs  1  b;
INIT  DptSchdlrs  1  c;
INIT  DptSchdlrs  1  d;
INIT  DptSchdlrs  1  e;
INIT  DptSchdlrs  1  f;
INIT  DptSchdlrs  1  g;
INIT  DptSchdlrs  1  h;
INIT  DptSchdlrs  1  i;
INIT  DptSchdlrs  1  j;
INIT  DptSchdlrs  1  k;
INIT  DptSchdlrs  1  l;
INIT  DptSchdlrs  1  m;
INIT  DptSchdlrs  1  n;
INIT  DptSchdlrs  1  o;
INIT  DptSchdlrs  1  p;
INIT  DptSchdlrs  1  q;
INIT  DptSchdlrs  1  r;
INIT  DptSchdlrs  1  s;
INIT  DptSchdlrs  1  t;
INIT  DptSchdlrs  1  u;
INIT  DptSchdlrs  1  v;
INIT  DptSchdlrs  1  w;
INIT  DptSchdlrs  1  x;


INIT AppSignals 1;
INIT AppSignalsa 1;
```

```
/ Reseed all random numbers streams
SEEDALL Seeds[nReplications-1];

/simulate

SIMULATEUNTIL ' SimTime>=24*60*60 ';

PRINT StdOutput "%12.2f %9.2f %8.2f | %12.2f %9.2f %9.2f\n"

            ArvsPerHr  ArvMaxWt  ArvAveWt  DptsPerHr  DptMaxWt   DptAveWt ;

/Collect some results
/Arrivals
COLLECT ArvPerHr  ArvsPerHr;
COLLECT ArvMxWt   ArvMaxWt;
COLLECT ArvAvWt   ArvAveWt;

/Departures
COLLECT DptPerHr  DptsPerHr;
COLLECT DptMxWt   DptMaxWt;
COLLECT DptAvWt   DptAveWt;


IF DaysToSimulate<=1;
      ENDMODEL;
ENDIF;


/*************************************************************************
/Number of replications decremented
ASSIGN   nReplications  nReplications-1;

/End of while loop
WEND;
PRINT StdOutput
"================================|================================\n";
PRINT StdOutput "Mean %7.2f %9.2f %8.2f | %12.2f %9.2f %9.2f\n"

                        ArvPerHr.AveVal
                        ArvMxWt.AveVal
                        ArvAvWt.AveVal
                        DptPerHr.AveVal
                        DptMxWt.AveVal
                        DptAvWt.AveVal;


PRINT StdOutput "SD %9.2f %9.2f %8.2f | %12.2f %9.2f %9.2f\n"

                        ArvPerHr.SDVal
                        ArvMxWt.SDVal
                        ArvAvWt.SDVal
                        DptPerHr.SDVal
                        DptMxWt.SDVal
                        DptAvWt.SDVal;


REPORT;
```

APPENDIX C

Section of a Trace File for Visualizing Airport Operations

This appendix presents a portion of VITASCOPE Trace File for visualizing airport operations at DTW (scenario I). This trace file has been generated automatically during a simulation run by the instrumented simulation model presented in Appendix B.

```
PATH AlignPath1
      '(12477.7,1500,-11003.30)'
      '(12477.648,1500,-11003.330)';


NONDIRECPATH FirstSCAP
'(12477.648,1500,-11003.330)'
'(3406.164,316,-3375.419)';

NONDIRECPATH LastSCAP
'(3406.164.471,316,-3375.419)'
'(1726.8,0,-408.643)';

PATH PLand1
      '(1726.8,0,-408.643)'
      '(1034.906,0,883.118)';

PATH PLand2
      '(1034.906,0,883.118)'
      '(508.815.415,0,1867.593)';


PATH TaW2WJ
'(1034.906,0,883.118)'
'(744.419,0,965.596)'
'(555.969,0,1311.656)'
'(349.941,0,1329.344)';

PATH PPF2Run21R
   '(349.941,0,1329.344)'
   '(336.050,0,1322.398)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)';
```

```
PATH TaW1W
      '(508.815.415,0,1867.593)'
      '(290.039,0,1794.669)'
    '(299.983,0,1773.565)';

PATH WT5PPF2Run21R
       '(299.983,0,1773.565)'
      '(441.096,0,1523.808)'
      '(342.127,0,1430.048)'
    '(284.830,0,1419.631)'
   '(336.050,0,1329.344)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)';



PATH  R21RF2Gatec
'(750.133,0,263.263)'
'(579.131,0,75.744)'
'(294.380,0,-334.019)'
'(363.831,0,-406.943)'
'(186.366,0,-646.161)'
'(248.814,0,-768.153)';


PATH AlignPath2
      '(-6855,1500,-13073)'
      '(-6853.208,1500,-13072.443)';


NONDIRECPATH FirstSCAPa
'(-6853.208,1500,-13072.443)'
'(820.145,316,-4038.011)';


NONDIRECPATH LastSCAPa
'(820.145,316,-4038.011)'
'(-841.169,0,-1106.630)';

PATH PLanda
      '(-841.169,0,-1106.630)'
   '(-1673.702,0,403.903)';

PATH PLandb
       '(-1673.702,0,403.903)'
      '(-2135.989,0,1239.925)';


PATH TaA42A6
      '(-1673.702,0,403.903)'
      '(-1611.196,0,534.124)';
```

```
PATH A6V2Run22L1
      '(-1611.196,0,534.124)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)';


PATH TaA12A6
      '(-2135.989,0,1239.925)'
      '(-1991.443,0,1325.871)';


PATH A6V2Run22L2
'(-1991.443,0,1325.871)'
'(-1715.373,0,841.447)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)';



PATH R22LV2Gatec
 '(-79.790,0,-934.775)'
'(86.893,0,-893.104)'
'(165.026,0,-929.566)'
'(279.621,0,-882.686)';



PATH GaCY2R22L
      '(312.292,0,-919.148)'
      '(715.863,0,-1744.753)'
     '(584.903,0,-1807.295)';

PATH ONRun22L
      '(584.903,0,-1807.295)'
      '(481.465,0,-1869.766)'
'(442.398,0,-1776.006)';


PATH RollingR22L
      '(442.398,0,-1776.006)'
       '(-1122.431,0,1110.572)';


PATH TakeOffR22L
      '(-1122.431,0,1110.572)'
      '(-3399.300,500,5589.976)';
```

```
PATH GaCVM2R21R
      '(278.319,0,-760.278)'
      '(372.078,0,-596.199)'
      '(848.689,0,-564.946)'
      '(929.861,0,-497.230)'
   '(1248.469,0,-1007.699)'
      '(1458.126,0,-1440.034)'
     '(1544.072,0,-1588.487)';

PATH ONRun21R
      '(1544.072,0,-1588.487)'
      '(1645.645,0,-1525.981)'
'(1606.579,0,-1447.848)';


PATH RollingR21R
      '(1606.579,0,-1447.848)'
       '(513.152,0,582.740)';



PATH TakeOffR21R
      '(513.152,0,582.740)'
      '(-1765.401,500,5054.076)';
TIME 0;

VIEWPOINT Overview '(-2801, 1367.13, 2391.87)'
'(-2800.35,1366.55,2391.38)' '(0.45,0.81,-0.37)';
VIEWRATIO 40;

CLASS AirSide DTW.ac;
CREATE AirSide AirSide;
PLACE AirSide AT (0,0,0);
CLASS Type0 DC10.osg;
SET CLASS Type0 RGP 30;
SET CLASS Type0 AFTCLEARANCE 75;
CLASS Type1 Boeing737.osg;
SET CLASS Type1 RGP 25;
SET CLASS Type1 AFTCLEARANCE 60;
CLASS Type2 Avro.osg;
SET CLASS Type2 RGP 25;
SET CLASS Type2 AFTCLEARANCE 60;
TIME 3.959083;
CREATE Plane1 Type1;
PLACE Plane1 ON GaCVM2R21R;
MOVE Plane1 GaCVM2R21R 230.000000;
TIME 40.431462;
CREATE Plane2 Type0;
PLACE Plane2 ON GaCY2R22L;
MOVE Plane2 GaCY2R22L 115.000000;
TIME 72.516855;
CREATE Plane3 Type1;
PLACE Plane3 ON GaCVM2R21R;
MOVE Plane3 GaCVM2R21R 230.000000;
TIME 100.374411;
CREATE Plane4 Type2;
```

```
PLACE Plane4 ON GaCVM2R21R;
MOVE Plane4 GaCVM2R21R 230.000000;
TIME 155.431462;
MOVE Plane2 ONRun22L 17.000000;
TIME 172.431462;
MOVE Plane2 RollingR22L 43.630666;
TIME 216.062128;
MOVE Plane2 TakeOffR22L 51.135316;
TIME 233.959083;
MOVE Plane1 ONRun21R 15.000000;
TIME 248.959083;
MOVE Plane1 RollingR21R 39.771558;
TIME 267.197444;
DESTROY Plane2;
TIME 284.900611;
CREATE Plane5 Type2;
TIME 284.900611;
PLACE Plane5 ON AlignPath2;
TIME 284.900611;
MOVE Plane5 FirstSCAPa 226.923077;
TIME 288.730641;
MOVE Plane1 TakeOffR21R 83.404177;
TIME 302.516855;
MOVE Plane3 ONRun21R 15.000000;
TIME 317.516855;
MOVE Plane3 RollingR21R 55.924834;
TIME 372.134817;
DESTROY Plane1;
TIME 373.441689;
MOVE Plane3 TakeOffR21R 76.299804;
TIME 373.441689;
MOVE Plane4 ONRun21R 15.000000;
TIME 393.591475;
MOVE Plane4 RollingR21R 44.469385;
TIME 416.563373;
CREATE Plane6 Type1;
PLACE Plane6 ON GaCVM2R21R;
MOVE Plane6 GaCVM2R21R 230.000000;
TIME 438.060860;
MOVE Plane4 TakeOffR21R 109.398337;
TIME 449.741493;
DESTROY Plane3;
TIME 511.823688;
MOVE Plane5 LastSCAPa 61.538462;
TIME 545.004144;
CREATE Plane7 Type0;
TIME 545.004144;
PLACE Plane7 ON AlignPath1;
TIME 545.004144;
MOVE Plane7 FirstSCAP 157.333333;
TIME 547.459197;
DESTROY Plane4;
TIME 573.362150;
MOVE Plane5 PLanda 39.145299;
TIME 603.361599;
CREATE Plane8 Type2;
TIME 612.507449;
```

```
MOVE Plane5 TaA42A6 30.000000;
TIME 641.512843;
CREATE Plane9 Type2;
PLACE Plane9 ON GaCVM2R21R;
MOVE Plane9 GaCVM2R21R 230.000000;
TIME 642.507449;
MOVE Plane5 A6V2Run22L1 270.000000;
TIME 646.563373;
MOVE Plane6 ONRun21R 15.000000;
TIME 661.563373;
MOVE Plane6 RollingR21R 47.507148;
TIME 669.777553;
PLACE Plane8 ON AlignPath1;
TIME 669.777553;
MOVE Plane8 FirstSCAP 226.923077;
TIME 680.518840;
CREATE Plane10 Type1;
PLACE Plane10 ON GaCVM2R21R;
MOVE Plane10 GaCVM2R21R 230.000000;
TIME 702.337478;
MOVE Plane7 LastSCAP 42.666667;
TIME 709.070521;
MOVE Plane6 TakeOffR21R 76.456999;
TIME 722.906611;
CREATE Plane11 Type1;
PLACE Plane11 ON GaCVM2R21R;
MOVE Plane11 GaCVM2R21R 230.000000;
TIME 745.004144;
MOVE Plane7 PLand1 23.496296;
TIME 768.500441;
MOVE Plane7 PLand2 31.200000;
TIME 777.837652;
CREATE Plane12 Type1;
PLACE Plane12 ON GaCVM2R21R;
MOVE Plane12 GaCVM2R21R 230.000000;
TIME 785.527520;
DESTROY Plane6;
TIME 794.629994;
CREATE Plane13 Type0;
PLACE Plane13 ON GaCY2R22L;
MOVE Plane13 GaCY2R22L 115.000000;
TIME 799.700441;
MOVE Plane7 TaW1W 20.000000;
TIME 810.260260;
CREATE Plane14 Type0;
PLACE Plane14 ON GaCY2R22L;
MOVE Plane14 GaCY2R22L 115.000000;
TIME 819.700441;
MOVE Plane7 WT5PPF2Run21R 154.000000;
TIME 851.832079;
CREATE Plane15 Type0;
TIME 851.832079;
PLACE Plane15 ON AlignPath2;
TIME 851.832079;
MOVE Plane15 FirstSCAPa 157.333333;
TIME 869.016024;
CREATE Plane16 Type0;
```

```
PLACE Plane16 ON GaCY2R22L;
MOVE Plane16 GaCY2R22L 115.000000;
TIME 871.512843;
MOVE Plane9 ONRun21R 15.000000;
TIME 886.512843;
MOVE Plane9 RollingR21R 60.119709;
TIME 896.700630;
MOVE Plane8 LastSCAP 61.538462;
TIME 909.629994;
MOVE Plane13 ONRun22L 17.000000;
TIME 926.629994;
MOVE Plane13 RollingR22L 36.699850;
TIME 946.632553;
MOVE Plane9 TakeOffR21R 92.275119;
TIME 946.632553;
MOVE Plane10 ONRun21R 15.000000;
TIME 958.239092;
MOVE Plane8 PLand1 33.888889;
TIME 963.329844;
MOVE Plane13 TakeOffR22L 49.950324;
TIME 963.329844;
MOVE Plane5 R22LV2Gatec 32.000000;
TIME 963.329844;
MOVE Plane14 ONRun22L 17.000000;
TIME 973.700441;
MOVE Plane7 R21RF2Gatec 109.000000;
TIME 992.127980;
MOVE Plane8 TaW2WJ 83.000000;
TIME 995.329844;
DESTROY Plane5;
TIME 995.329844;
MOVE Plane14 RollingR22L 36.930407;
TIME 1001.367849;
CREATE Plane17 Type1;
TIME 1001.367849;
PLACE Plane17 ON AlignPath1;
TIME 1001.367849;
MOVE Plane17 FirstSCAP 173.529412;
TIME 1009.165412;
MOVE Plane15 LastSCAPa 42.666667;
TIME 1013.280168;
DESTROY Plane13;
TIME 1032.260251;
MOVE Plane14 TakeOffR22L 54.233481;
TIME 1032.260251;
MOVE Plane16 ONRun22L 17.000000;
TIME 1038.907671;
DESTROY Plane9;
TIME 1051.832079;
MOVE Plane15 PLanda 27.140741;
TIME 1056.994129;
MOVE Plane16 RollingR22L 35.853252;
TIME 1075.127980;
MOVE Plane8 PPF2Run21R 130.000000;
TIME 1078.972820;
MOVE Plane15 PLandb 27.093333;
```

```
TIME 1082.700441;
DESTROY Plane7;
TIME 1082.700441;
MOVE Plane10 RollingR21R 48.361590;
TIME 1086.493732;
DESTROY Plane14;
TIME 1092.847381;
MOVE Plane16 TakeOffR22L 57.379651;
TIME 1106.066153;
MOVE Plane15 TaA12A6 20.000000;
TIME 1109.946436;
CREATE Plane18 Type2;
PLACE Plane18 ON GaCVM2R21R;
MOVE Plane18 GaCVM2R21R 230.000000;
TIME 1126.066153;
MOVE Plane15 A6V2Run22L2 350.000000;
TIME 1131.062030;
MOVE Plane10 TakeOffR21R 74.617986;
TIME 1131.062030;
MOVE Plane11 ONRun21R 15.000000;
TIME 1150.227032;
DESTROY Plane16;
TIME 1153.715389;
CREATE Plane19 Type2;
TIME 1171.580364;
MOVE Plane11 RollingR21R 41.506106;
TIME 1174.897261;
MOVE Plane17 LastSCAP 47.058824;
TIME 1180.331757;
PLACE Plane19 ON AlignPath1;
TIME 1180.331757;
MOVE Plane19 FirstSCAP 226.923077;
TIME 1205.680017;
DESTROY Plane10;
TIME 1213.086471;
MOVE Plane11 TakeOffR21R 83.942462;
TIME 1213.086471;
MOVE Plane12 ONRun21R 15.000000;
TIME 1221.956085;
MOVE Plane17 PLand1 25.915033;
TIME 1225.530628;
MOVE Plane8 R21RF2Gatec 109.000000;
TIME 1247.871117;
MOVE Plane17 TaW2WJ 83.000000;
TIME 1250.933833;
CREATE Plane20 Type2;
PLACE Plane20 ON GaCVM2R21R;
MOVE Plane20 GaCVM2R21R 230.000000;
TIME 1254.228830;
CREATE Plane21 Type0;
PLACE Plane21 ON GaCY2R22L;
MOVE Plane21 GaCY2R22L 115.000000;
TIME 1297.028932;
DESTROY Plane11;
TIME 1330.871117;
MOVE Plane17 PPF2Run21R 130.000000;
```

```
TIME 1334.530628;
DESTROY Plane8;
TIME 1334.530628;
MOVE Plane12 RollingR21R 32.697858;
TIME 1367.228485;
MOVE Plane12 TakeOffR21R 77.577380;
TIME 1367.228485;
MOVE Plane18 ONRun21R 15.000000;
TIME 1369.228830;
MOVE Plane21 ONRun22L 17.000000;
TIME 1373.920546;
CREATE Plane22 Type0;
PLACE Plane22 ON GaCY2R22L;
MOVE Plane22 GaCY2R22L 115.000000;
TIME 1382.228485;
MOVE Plane18 RollingR21R 57.291681;
TIME 1386.228830;
MOVE Plane21 RollingR22L 37.742253;
TIME 1403.109709;
CREATE Plane23 Type1;
TIME 1403.109709;
PLACE Plane23 ON AlignPath1;
TIME 1403.109709;
MOVE Plane23 FirstSCAP 173.529412;
TIME 1407.254834;
MOVE Plane19 LastSCAP 61.538462;
TIME 1423.971083;
MOVE Plane21 TakeOffR22L 51.552564;
TIME 1439.520166;
MOVE Plane18 TakeOffR21R 110.758451;
TIME 1444.805866;
DESTROY Plane12;
TIME 1460.871117;
MOVE Plane17 R21RF2Gatec 109.000000;
TIME 1468.793295;
MOVE Plane19 PLand1 33.888889;
TIME 1475.523647;
DESTROY Plane21;
TIME 1476.066153;
MOVE Plane15 R22LV2Gatec 32.000000;
TIME 1480.933833;
MOVE Plane20 ONRun21R 15.000000;
TIME 1484.454119;
CREATE Plane24 Type0;
PLACE Plane24 ON GaCY2R22L;
MOVE Plane24 GaCY2R22L 115.000000;
TIME 1488.920546;
MOVE Plane22 ONRun22L 17.000000;
TIME 1502.682184;
MOVE Plane19 TaW2WJ 83.000000;
TIME 1508.066153;
DESTROY Plane15;
TIME 1508.066153;
MOVE Plane22 RollingR22L 43.794008;
TIME 1550.278617;
DESTROY Plane18;
```

```
TIME 1551.860161;
MOVE Plane22 TakeOffR22L 54.707499;
TIME 1569.871117;
DESTROY Plane17;
TIME 1569.871117;
MOVE Plane20 RollingR21R 43.157156;
TIME 1576.639121;
MOVE Plane23 LastSCAP 47.058824;
TIME 1585.682184;
MOVE Plane19 PPF2Run21R 130.000000;
TIME 1599.454119;
MOVE Plane24 ONRun22L 17.000000;
TIME 1606.567660;
DESTROY Plane22;
TIME 1613.028273;
MOVE Plane20 TakeOffR21R 88.136260;
TIME 1616.454119;
MOVE Plane24 RollingR22L 40.934043;
TIME 1623.697945;
MOVE Plane23 PLand1 25.915033;
TIME 1649.612977;
MOVE Plane23 TaW2WJ 83.000000;
TIME 1657.388161;
MOVE Plane24 TakeOffR22L 53.124123;
TIME 1667.681421;
CREATE Plane25 Type1;
PLACE Plane25 ON GaCVM2R21R;
MOVE Plane25 GaCVM2R21R 230.000000;
TIME 1680.272916;
CREATE Plane26 Type0;
TIME 1680.272916;
PLACE Plane26 ON AlignPath1;
TIME 1680.272916;
MOVE Plane26 FirstSCAP 157.333333;
TIME 1701.164533;
DESTROY Plane20;
TIME 1704.440187;
CREATE Plane27 Type1;
PLACE Plane27 ON GaCVM2R21R;
MOVE Plane27 GaCVM2R21R 230.000000;
TIME 1710.512284;
DESTROY Plane24;
TIME 1715.682184;
MOVE Plane19 R21RF2Gatec 109.000000;
TIME 1727.559682;
CREATE Plane28 Type2;
PLACE Plane28 ON GaCVM2R21R;
MOVE Plane28 GaCVM2R21R 230.000000;
TIME 1729.508315;
CREATE Plane29 Type2;
PLACE Plane29 ON GaCVM2R21R;
MOVE Plane29 GaCVM2R21R 230.000000;
TIME 1732.612977;
MOVE Plane23 PPF2Run21R 130.000000;
TIME 1800.423727;
CREATE Plane30 Type2;
PLACE Plane30 ON GaCVM2R21R;
```

```
MOVE Plane30 GaCVM2R21R 230.000000;
TIME 1824.682184;
DESTROY Plane19;
TIME 1837.606250;
MOVE Plane26 LastSCAP 42.666667;
TIME 1862.612977;
MOVE Plane23 R21RF2Gatec 109.000000;
TIME 1880.272916;
MOVE Plane26 PLand1 23.496296;
TIME 1897.681421;
MOVE Plane25 ONRun21R 15.000000;
TIME 1903.769213;
MOVE Plane26 PLand2 31.200000;
TIME 1930.788643;
CREATE Plane31 Type2;
PLACE Plane31 ON GaCVM2R21R;
MOVE Plane31 GaCVM2R21R 230.000000;
TIME 1934.969213;
MOVE Plane26 TaW1W 20.000000;
TIME 1935.288859;
CREATE Plane32 Type1;
TIME 1935.288859;
PLACE Plane32 ON AlignPath1;
TIME 1935.288859;
MOVE Plane32 FirstSCAP 173.529412;
TIME 1954.969213;
MOVE Plane26 WT5PPF2Run21R 154.000000;
TIME 1971.612977;
DESTROY Plane23;
TIME 1971.612977;
MOVE Plane25 RollingR21R 22.952258;
TIME 1994.565236;
MOVE Plane25 TakeOffR21R 86.406115;
TIME 1994.565236;
MOVE Plane27 ONRun21R 15.000000;
TIME 2007.370127;
CREATE Plane33 Type1;
TIME 2007.370127;
PLACE Plane33 ON AlignPath2;
TIME 2007.370127;
MOVE Plane33 FirstSCAPa 173.529412;
TIME 2022.834627;
CREATE Plane34 Type2;
TIME 2030.165771;
CREATE Plane35 Type2;
PLACE Plane35 ON GaCVM2R21R;
MOVE Plane35 GaCVM2R21R 230.000000;
TIME 2038.308297;
PLACE Plane34 ON AlignPath1;
TIME 2038.308297;
MOVE Plane34 FirstSCAP 226.923077;
TIME 2039.363271;
MOVE Plane27 RollingR21R 48.541786;
TIME 2064.856099;
CREATE Plane36 Type0;
TIME 2080.971350;
DESTROY Plane25;
```

```
TIME 2087.905057;
MOVE Plane27 TakeOffR21R 90.324779;
TIME 2087.905057;
MOVE Plane28 ONRun21R 15.000000;
TIME 2106.857518;
MOVE Plane28 RollingR21R 43.553386;
TIME 2108.818270;
MOVE Plane32 LastSCAP 47.058824;
TIME 2118.063721;
CREATE Plane37 Type1;
PLACE Plane37 ON GaCVM2R21R;
MOVE Plane37 GaCVM2R21R 230.000000;
TIME 2150.410903;
MOVE Plane28 TakeOffR21R 101.163242;
TIME 2150.410903;
MOVE Plane29 ONRun21R 15.000000;
TIME 2153.935070;
PLACE Plane36 ON AlignPath1;
TIME 2153.935070;
MOVE Plane36 FirstSCAP 157.333333;
TIME 2155.877094;
MOVE Plane32 PLand1 25.915033;
TIME 2161.195614;
MOVE Plane26 R21RF2Gatec 109.000000;
TIME 2178.229836;
DESTROY Plane27;
TIME 2180.899539;
MOVE Plane33 LastSCAPa 47.058824;
TIME 2181.792127;
MOVE Plane32 TaW2WJ 83.000000;
TIME 2227.958363;
MOVE Plane33 PLanda 29.934641;
TIME 2251.574146;
DESTROY Plane28;
TIME 2257.893003;
MOVE Plane33 TaA42A6 30.000000;
TIME 2264.792127;
MOVE Plane32 PPF2Run21R 130.000000;
TIME 2265.231374;
MOVE Plane34 LastSCAP 61.538462;
TIME 2270.195614;
DESTROY Plane26;
TIME 2287.893003;
MOVE Plane33 A6V2Run22L1 270.000000;
TIME 2311.268404;
MOVE Plane36 LastSCAP 42.666667;
TIME 2326.769836;
MOVE Plane34 PLand1 33.888889;
TIME 2346.620454;
CREATE Plane38 Type0;
TIME 2346.620454;
PLACE Plane38 ON AlignPath2;
TIME 2346.620454;
MOVE Plane38 FirstSCAPa 157.333333;
TIME 2353.935070;
MOVE Plane36 PLand1 23.496296;
```

```
TIME 2360.658725;
MOVE Plane34 TaW2WJ 83.000000;
TIME 2377.431367;
MOVE Plane29 RollingR21R 55.688103;
TIME 2377.431367;
MOVE Plane36 PLand2 31.200000;
TIME 2377.822170;
CREATE Plane39 Type1;
PLACE Plane39 ON GaCVM2R21R;
MOVE Plane39 GaCVM2R21R 230.000000;
TIME 2408.631367;
MOVE Plane36 TaW1W 20.000000;
TIME 2433.119470;
MOVE Plane29 TakeOffR21R 83.179608;
TIME 2433.119470;
MOVE Plane30 ONRun21R 15.000000;
TIME 2446.437059;
MOVE Plane32 R21RF2Gatec 109.000000;
TIME 2446.437059;
MOVE Plane34 PPF2Run21R 130.000000;
TIME 2503.953787;
MOVE Plane38 LastSCAPa 42.666667;
TIME 2516.299078;
DESTROY Plane29;
TIME 2527.753511;
CREATE Plane40 Type2;
PLACE Plane40 ON GaCVM2R21R;
MOVE Plane40 GaCVM2R21R 230.000000;
TIME 2546.620454;
MOVE Plane38 PLanda 27.140741;
TIME 2548.712701;
CREATE Plane41 Type0;
TIME 2548.712701;
PLACE Plane41 ON AlignPath1;
TIME 2548.712701;
MOVE Plane41 FirstSCAP 157.333333;
TIME 2555.437059;
DESTROY Plane32;
TIME 2555.437059;
MOVE Plane30 RollingR21R 39.176668;
TIME 2557.332181;
CREATE Plane42 Type1;
PLACE Plane42 ON GaCVM2R21R;
MOVE Plane42 GaCVM2R21R 230.000000;
TIME 2557.893003;
MOVE Plane33 R22LV2Gatec 32.000000;
TIME 2573.761194;
MOVE Plane38 PLandb 27.093333;
TIME 2589.893003;
DESTROY Plane33;
TIME 2594.613727;
MOVE Plane30 TakeOffR21R 112.516452;
TIME 2594.613727;
MOVE Plane31 ONRun21R 15.000000;
TIME 2600.854528;
MOVE Plane38 TaA12A6 20.000000;
TIME 2606.264891;
```

```
MOVE Plane34 R21RF2Gatec 109.000000;
TIME 2606.264891;
MOVE Plane36 WT5PPF2Run21R 154.000000;
TIME 2620.854528;
MOVE Plane38 A6V2Run22L2 350.000000;
TIME 2706.046034;
MOVE Plane41 LastSCAP 42.666667;
TIME 2707.130180;
DESTROY Plane30;
TIME 2708.184526;
CREATE Plane43 Type2;
TIME 2708.184526;
PLACE Plane43 ON AlignPath2;
TIME 2708.184526;
MOVE Plane43 FirstSCAPa 226.923077;
TIME 2715.264891;
DESTROY Plane34;
TIME 2748.712701;
MOVE Plane41 PLand1 23.496296;
TIME 2760.264891;
MOVE Plane36 R21RF2Gatec 109.000000;
TIME 2768.058912;
CREATE Plane44 Type0;
TIME 2772.208997;
MOVE Plane41 PLand2 31.200000;
TIME 2783.768945;
CREATE Plane45 Type1;
PLACE Plane45 ON GaCVM2R21R;
MOVE Plane45 GaCVM2R21R 230.000000;
TIME 2803.408997;
MOVE Plane41 TaW1W 20.000000;
TIME 2823.408997;
MOVE Plane41 WT5PPF2Run21R 154.000000;
TIME 2839.272890;
CREATE Plane46 Type2;
TIME 2848.888506;
CREATE Plane47 Type1;
PLACE Plane47 ON GaCVM2R21R;
MOVE Plane47 GaCVM2R21R 230.000000;
TIME 2869.264891;
DESTROY Plane36;
TIME 2869.264891;
MOVE Plane31 RollingR21R 50.665814;
TIME 2884.127498;
PLACE Plane44 ON AlignPath2;
TIME 2884.127498;
MOVE Plane44 FirstSCAPa 157.333333;
TIME 2919.930705;
MOVE Plane31 TakeOffR21R 107.945282;
TIME 2919.930705;
MOVE Plane35 ONRun21R 15.000000;
TIME 2934.930705;
MOVE Plane35 RollingR21R 58.413653;
TIME 2935.107603;
MOVE Plane43 LastSCAPa 61.538462;
TIME 2970.854528;
MOVE Plane38 R22LV2Gatec 32.000000;
```

```
TIME 2982.057157;
CREATE Plane48 Type2;
PLACE Plane48 ON GaCVM2R21R;
MOVE Plane48 GaCVM2R21R 230.000000;
TIME 2993.344359;
MOVE Plane35 TakeOffR21R 96.557776;
TIME 2993.344359;
MOVE Plane37 ONRun21R 15.000000;
TIME 2996.646064;
MOVE Plane43 PLanda 39.145299;
TIME 3002.854528;
DESTROY Plane38;
TIME 3015.773457;
MOVE Plane37 RollingR21R 26.483426;
TIME 3027.875987;
DESTROY Plane31;
TIME 3035.791363;
MOVE Plane43 TaA42A6 30.000000;
TIME 3041.460831;
MOVE Plane44 LastSCAPa 42.666667;
TIME 3042.256883;
MOVE Plane37 TakeOffR21R 67.118116;
```

APPENDIX C

Section of a Trace File for Visualizing Airport Operations

This appendix presents a portion of VITASCOPE Trace File for visualizing airport operations at DTW (scenario I). This trace file has been generated automatically during a simulation run by the instrumented simulation model presented in Appendix B.

```
PATH AlignPath1
      '(12477.7,1500,-11003.30)'
      '(12477.648,1500,-11003.330)';


NONDIRECPATH FirstSCAP
'(12477.648,1500,-11003.330)'
'(3406.164,316,-3375.419)';

NONDIRECPATH LastSCAP
'(3406.164.471,316,-3375.419)'
'(1726.8,0,-408.643)';

PATH PLand1
      '(1726.8,0,-408.643)'
      '(1034.906,0,883.118)';

PATH PLand2
      '(1034.906,0,883.118)'
      '(508.815.415,0,1867.593)';


PATH TaW2WJ
'(1034.906,0,883.118)'
'(744.419,0,965.596)'
'(555.969,0,1311.656)'
'(349.941,0,1329.344)';

PATH PPF2Run21R
   '(349.941,0,1329.344)'
   '(336.050,0,1322.398)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)';
```

```
PATH TaW1W
      '(508.815.415,0,1867.593)'
      '(290.039,0,1794.669)'
    '(299.983,0,1773.565)';

PATH WT5PPF2Run21R
       '(299.983,0,1773.565)'
      '(441.096,0,1523.808)'
      '(342.127,0,1430.048)'
    '(284.830,0,1419.631)'
   '(336.050,0,1329.344)'
    '(586.076,0,839.711)'
      '(568.713,0,818.875)'
      '(693.726,0,582.740)'
      '(731.924,0,610.521)'
    '(866.766,0,339.660)'
    '(750.133,0,263.263)';



PATH  R21RF2Gatec
'(750.133,0,263.263)'
'(579.131,0,75.744)'
'(294.380,0,-334.019)'
'(363.831,0,-406.943)'
'(186.366,0,-646.161)'
'(248.814,0,-768.153)';


PATH AlignPath2
      '(-6855,1500,-13073)'
      '(-6853.208,1500,-13072.443)';


NONDIRECPATH FirstSCAPa
'(-6853.208,1500,-13072.443)'
'(820.145,316,-4038.011)';


NONDIRECPATH LastSCAPa
'(820.145,316,-4038.011)'
'(-841.169,0,-1106.630)';

PATH PLanda
      '(-841.169,0,-1106.630)'
   '(-1673.702,0,403.903)';

PATH PLandb
       '(-1673.702,0,403.903)'
      '(-2135.989,0,1239.925)';


PATH TaA42A6
      '(-1673.702,0,403.903)'
      '(-1611.196,0,534.124)';
```

```
PATH A6V2Run22L1
      '(-1611.196,0,534.124)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)';


PATH TaA12A6
      '(-2135.989,0,1239.925)'
      '(-1991.443,0,1325.871)';


PATH A6V2Run22L2
'(-1991.443,0,1325.871)'
'(-1715.373,0,841.447)'
      '(-1575.151,0,570.586)'
      '(-1179.278,0,-127.401)'
      '(-900.186,0,-667.387)'
     '(-491.290,0,-429.515)'
     '(-372.355,0,-427.779)'
      '(-95.417,0,-945.192)'
     '(-79.790,0,-934.775)';



PATH R22LV2Gatec
 '(-79.790,0,-934.775)'
'(86.893,0,-893.104)'
'(165.026,0,-929.566)'
'(279.621,0,-882.686)';



PATH GaCY2R22L
      '(312.292,0,-919.148)'
      '(715.863,0,-1744.753)'
     '(584.903,0,-1807.295)';

PATH ONRun22L
      '(584.903,0,-1807.295)'
      '(481.465,0,-1869.766)'
'(442.398,0,-1776.006)';


PATH RollingR22L
      '(442.398,0,-1776.006)'
       '(-1122.431,0,1110.572)';


PATH TakeOffR22L
      '(-1122.431,0,1110.572)'
      '(-3399.300,500,5589.976)';
```

```
PATH GaCVM2R21R
      '(278.319,0,-760.278)'
      '(372.078,0,-596.199)'
      '(848.689,0,-564.946)'
      '(929.861,0,-497.230)'
   '(1248.469,0,-1007.699)'
      '(1458.126,0,-1440.034)'
     '(1544.072,0,-1588.487)';

PATH ONRun21R
      '(1544.072,0,-1588.487)'
      '(1645.645,0,-1525.981)'
'(1606.579,0,-1447.848)';


PATH RollingR21R
      '(1606.579,0,-1447.848)'
       '(513.152,0,582.740)';



PATH TakeOffR21R
      '(513.152,0,582.740)'
      '(-1765.401,500,5054.076)';
TIME 0;

VIEWPOINT Overview '(-2801, 1367.13, 2391.87)'
'(-2800.35,1366.55,2391.38)' '(0.45,0.81,-0.37)';
VIEWRATIO 40;

CLASS AirSide DTW.ac;
CREATE AirSide AirSide;
PLACE AirSide AT (0,0,0);
CLASS Type0 DC10.osg;
SET CLASS Type0 RGP 30;
SET CLASS Type0 AFTCLEARANCE 75;
CLASS Type1 Boeing737.osg;
SET CLASS Type1 RGP 25;
SET CLASS Type1 AFTCLEARANCE 60;
CLASS Type2 Avro.osg;
SET CLASS Type2 RGP 25;
SET CLASS Type2 AFTCLEARANCE 60;
TIME 3.959083;
CREATE Plane1 Type1;
PLACE Plane1 ON GaCVM2R21R;
MOVE Plane1 GaCVM2R21R 230.000000;
TIME 40.431462;
CREATE Plane2 Type0;
PLACE Plane2 ON GaCY2R22L;
MOVE Plane2 GaCY2R22L 115.000000;
TIME 72.516855;
CREATE Plane3 Type1;
PLACE Plane3 ON GaCVM2R21R;
MOVE Plane3 GaCVM2R21R 230.000000;
TIME 100.374411;
CREATE Plane4 Type2;
```

```
PLACE Plane4 ON GaCVM2R21R;
MOVE Plane4 GaCVM2R21R 230.000000;
TIME 155.431462;
MOVE Plane2 ONRun22L 17.000000;
TIME 172.431462;
MOVE Plane2 RollingR22L 43.630666;
TIME 216.062128;
MOVE Plane2 TakeOffR22L 51.135316;
TIME 233.959083;
MOVE Plane1 ONRun21R 15.000000;
TIME 248.959083;
MOVE Plane1 RollingR21R 39.771558;
TIME 267.197444;
DESTROY Plane2;
TIME 284.900611;
CREATE Plane5 Type2;
TIME 284.900611;
PLACE Plane5 ON AlignPath2;
TIME 284.900611;
MOVE Plane5 FirstSCAPa 226.923077;
TIME 288.730641;
MOVE Plane1 TakeOffR21R 83.404177;
TIME 302.516855;
MOVE Plane3 ONRun21R 15.000000;
TIME 317.516855;
MOVE Plane3 RollingR21R 55.924834;
TIME 372.134817;
DESTROY Plane1;
TIME 373.441689;
MOVE Plane3 TakeOffR21R 76.299804;
TIME 373.441689;
MOVE Plane4 ONRun21R 15.000000;
TIME 393.591475;
MOVE Plane4 RollingR21R 44.469385;
TIME 416.563373;
CREATE Plane6 Type1;
PLACE Plane6 ON GaCVM2R21R;
MOVE Plane6 GaCVM2R21R 230.000000;
TIME 438.060860;
MOVE Plane4 TakeOffR21R 109.398337;
TIME 449.741493;
DESTROY Plane3;
TIME 511.823688;
MOVE Plane5 LastSCAPa 61.538462;
TIME 545.004144;
CREATE Plane7 Type0;
TIME 545.004144;
PLACE Plane7 ON AlignPath1;
TIME 545.004144;
MOVE Plane7 FirstSCAP 157.333333;
TIME 547.459197;
DESTROY Plane4;
TIME 573.362150;
MOVE Plane5 PLanda 39.145299;
TIME 603.361599;
CREATE Plane8 Type2;
TIME 612.507449;
```

```
MOVE Plane5 TaA42A6 30.000000;
TIME 641.512843;
CREATE Plane9 Type2;
PLACE Plane9 ON GaCVM2R21R;
MOVE Plane9 GaCVM2R21R 230.000000;
TIME 642.507449;
MOVE Plane5 A6V2Run22L1 270.000000;
TIME 646.563373;
MOVE Plane6 ONRun21R 15.000000;
TIME 661.563373;
MOVE Plane6 RollingR21R 47.507148;
TIME 669.777553;
PLACE Plane8 ON AlignPath1;
TIME 669.777553;
MOVE Plane8 FirstSCAP 226.923077;
TIME 680.518840;
CREATE Plane10 Type1;
PLACE Plane10 ON GaCVM2R21R;
MOVE Plane10 GaCVM2R21R 230.000000;
TIME 702.337478;
MOVE Plane7 LastSCAP 42.666667;
TIME 709.070521;
MOVE Plane6 TakeOffR21R 76.456999;
TIME 722.906611;
CREATE Plane11 Type1;
PLACE Plane11 ON GaCVM2R21R;
MOVE Plane11 GaCVM2R21R 230.000000;
TIME 745.004144;
MOVE Plane7 PLand1 23.496296;
TIME 768.500441;
MOVE Plane7 PLand2 31.200000;
TIME 777.837652;
CREATE Plane12 Type1;
PLACE Plane12 ON GaCVM2R21R;
MOVE Plane12 GaCVM2R21R 230.000000;
TIME 785.527520;
DESTROY Plane6;
TIME 794.629994;
CREATE Plane13 Type0;
PLACE Plane13 ON GaCY2R22L;
MOVE Plane13 GaCY2R22L 115.000000;
TIME 799.700441;
MOVE Plane7 TaW1W 20.000000;
TIME 810.260260;
CREATE Plane14 Type0;
PLACE Plane14 ON GaCY2R22L;
MOVE Plane14 GaCY2R22L 115.000000;
TIME 819.700441;
MOVE Plane7 WT5PPF2Run21R 154.000000;
TIME 851.832079;
CREATE Plane15 Type0;
TIME 851.832079;
PLACE Plane15 ON AlignPath2;
TIME 851.832079;
MOVE Plane15 FirstSCAPa 157.333333;
TIME 869.016024;
CREATE Plane16 Type0;
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PLACE Plane16 ON GaCY2R22L;
MOVE Plane16 GaCY2R22L 115.000000;
TIME 871.512843;
MOVE Plane9 ONRun21R 15.000000;
TIME 886.512843;
MOVE Plane9 RollingR21R 60.119709;
TIME 896.700630;
MOVE Plane8 LastSCAP 61.538462;
TIME 909.629994;
MOVE Plane13 ONRun22L 17.000000;
TIME 926.629994;
MOVE Plane13 RollingR22L 36.699850;
TIME 946.632553;
MOVE Plane9 TakeOffR21R 92.275119;
TIME 946.632553;
MOVE Plane10 ONRun21R 15.000000;
TIME 958.239092;
MOVE Plane8 PLand1 33.888889;
TIME 963.329844;
MOVE Plane13 TakeOffR22L 49.950324;
TIME 963.329844;
MOVE Plane5 R22LV2Gatec 32.000000;
TIME 963.329844;
MOVE Plane14 ONRun22L 17.000000;
TIME 973.700441;
MOVE Plane7 R21RF2Gatec 109.000000;
TIME 992.127980;
MOVE Plane8 TaW2WJ 83.000000;
TIME 995.329844;
DESTROY Plane5;
TIME 995.329844;
MOVE Plane14 RollingR22L 36.930407;
TIME 1001.367849;
CREATE Plane17 Type1;
TIME 1001.367849;
PLACE Plane17 ON AlignPath1;
TIME 1001.367849;
MOVE Plane17 FirstSCAP 173.529412;
TIME 1009.165412;
MOVE Plane15 LastSCAPa 42.666667;
TIME 1013.280168;
DESTROY Plane13;
TIME 1032.260251;
MOVE Plane14 TakeOffR22L 54.233481;
TIME 1032.260251;
MOVE Plane16 ONRun22L 17.000000;
TIME 1038.907671;
DESTROY Plane9;
TIME 1051.832079;
MOVE Plane15 PLanda 27.140741;
TIME 1056.994129;
MOVE Plane16 RollingR22L 35.853252;
TIME 1075.127980;
MOVE Plane8 PPF2Run21R 130.000000;
TIME 1078.972820;
MOVE Plane15 PLandb 27.093333;
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TIME 1082.700441;
DESTROY Plane7;
TIME 1082.700441;
MOVE Plane10 RollingR21R 48.361590;
TIME 1086.493732;
DESTROY Plane14;
TIME 1092.847381;
MOVE Plane16 TakeOffR22L 57.379651;
TIME 1106.066153;
MOVE Plane15 TaA12A6 20.000000;
TIME 1109.946436;
CREATE Plane18 Type2;
PLACE Plane18 ON GaCVM2R21R;
MOVE Plane18 GaCVM2R21R 230.000000;
TIME 1126.066153;
MOVE Plane15 A6V2Run22L2 350.000000;
TIME 1131.062030;
MOVE Plane10 TakeOffR21R 74.617986;
TIME 1131.062030;
MOVE Plane11 ONRun21R 15.000000;
TIME 1150.227032;
DESTROY Plane16;
TIME 1153.715389;
CREATE Plane19 Type2;
TIME 1171.580364;
MOVE Plane11 RollingR21R 41.506106;
TIME 1174.897261;
MOVE Plane17 LastSCAP 47.058824;
TIME 1180.331757;
PLACE Plane19 ON AlignPath1;
TIME 1180.331757;
MOVE Plane19 FirstSCAP 226.923077;
TIME 1205.680017;
DESTROY Plane10;
TIME 1213.086471;
MOVE Plane11 TakeOffR21R 83.942462;
TIME 1213.086471;
MOVE Plane12 ONRun21R 15.000000;
TIME 1221.956085;
MOVE Plane17 PLand1 25.915033;
TIME 1225.530628;
MOVE Plane8 R21RF2Gatec 109.000000;
TIME 1247.871117;
MOVE Plane17 TaW2WJ 83.000000;
TIME 1250.933833;
CREATE Plane20 Type2;
PLACE Plane20 ON GaCVM2R21R;
MOVE Plane20 GaCVM2R21R 230.000000;
TIME 1254.228830;
CREATE Plane21 Type0;
PLACE Plane21 ON GaCY2R22L;
MOVE Plane21 GaCY2R22L 115.000000;
TIME 1297.028932;
DESTROY Plane11;
TIME 1330.871117;
MOVE Plane17 PPF2Run21R 130.000000;
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TIME 1334.530628;
DESTROY Plane8;
TIME 1334.530628;
MOVE Plane12 RollingR21R 32.697858;
TIME 1367.228485;
MOVE Plane12 TakeOffR21R 77.577380;
TIME 1367.228485;
MOVE Plane18 ONRun21R 15.000000;
TIME 1369.228830;
MOVE Plane21 ONRun22L 17.000000;
TIME 1373.920546;
CREATE Plane22 Type0;
PLACE Plane22 ON GaCY2R22L;
MOVE Plane22 GaCY2R22L 115.000000;
TIME 1382.228485;
MOVE Plane18 RollingR21R 57.291681;
TIME 1386.228830;
MOVE Plane21 RollingR22L 37.742253;
TIME 1403.109709;
CREATE Plane23 Type1;
TIME 1403.109709;
PLACE Plane23 ON AlignPath1;
TIME 1403.109709;
MOVE Plane23 FirstSCAP 173.529412;
TIME 1407.254834;
MOVE Plane19 LastSCAP 61.538462;
TIME 1423.971083;
MOVE Plane21 TakeOffR22L 51.552564;
TIME 1439.520166;
MOVE Plane18 TakeOffR21R 110.758451;
TIME 1444.805866;
DESTROY Plane12;
TIME 1460.871117;
MOVE Plane17 R21RF2Gatec 109.000000;
TIME 1468.793295;
MOVE Plane19 PLand1 33.888889;
TIME 1475.523647;
DESTROY Plane21;
TIME 1476.066153;
MOVE Plane15 R22LV2Gatec 32.000000;
TIME 1480.933833;
MOVE Plane20 ONRun21R 15.000000;
TIME 1484.454119;
CREATE Plane24 Type0;
PLACE Plane24 ON GaCY2R22L;
MOVE Plane24 GaCY2R22L 115.000000;
TIME 1488.920546;
MOVE Plane22 ONRun22L 17.000000;
TIME 1502.682184;
MOVE Plane19 TaW2WJ 83.000000;
TIME 1508.066153;
DESTROY Plane15;
TIME 1508.066153;
MOVE Plane22 RollingR22L 43.794008;
TIME 1550.278617;
DESTROY Plane18;
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TIME 1551.860161;
MOVE Plane22 TakeOffR22L 54.707499;
TIME 1569.871117;
DESTROY Plane17;
TIME 1569.871117;
MOVE Plane20 RollingR21R 43.157156;
TIME 1576.639121;
MOVE Plane23 LastSCAP 47.058824;
TIME 1585.682184;
MOVE Plane19 PPF2Run21R 130.000000;
TIME 1599.454119;
MOVE Plane24 ONRun22L 17.000000;
TIME 1606.567660;
DESTROY Plane22;
TIME 1613.028273;
MOVE Plane20 TakeOffR21R 88.136260;
TIME 1616.454119;
MOVE Plane24 RollingR22L 40.934043;
TIME 1623.697945;
MOVE Plane23 PLand1 25.915033;
TIME 1649.612977;
MOVE Plane23 TaW2WJ 83.000000;
TIME 1657.388161;
MOVE Plane24 TakeOffR22L 53.124123;
TIME 1667.681421;
CREATE Plane25 Type1;
PLACE Plane25 ON GaCVM2R21R;
MOVE Plane25 GaCVM2R21R 230.000000;
TIME 1680.272916;
CREATE Plane26 Type0;
TIME 1680.272916;
PLACE Plane26 ON AlignPath1;
TIME 1680.272916;
MOVE Plane26 FirstSCAP 157.333333;
TIME 1701.164533;
DESTROY Plane20;
TIME 1704.440187;
CREATE Plane27 Type1;
PLACE Plane27 ON GaCVM2R21R;
MOVE Plane27 GaCVM2R21R 230.000000;
TIME 1710.512284;
DESTROY Plane24;
TIME 1715.682184;
MOVE Plane19 R21RF2Gatec 109.000000;
TIME 1727.559682;
CREATE Plane28 Type2;
PLACE Plane28 ON GaCVM2R21R;
MOVE Plane28 GaCVM2R21R 230.000000;
TIME 1729.508315;
CREATE Plane29 Type2;
PLACE Plane29 ON GaCVM2R21R;
MOVE Plane29 GaCVM2R21R 230.000000;
TIME 1732.612977;
MOVE Plane23 PPF2Run21R 130.000000;
TIME 1800.423727;
CREATE Plane30 Type2;
PLACE Plane30 ON GaCVM2R21R;
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MOVE Plane30 GaCVM2R21R 230.000000;
TIME 1824.682184;
DESTROY Plane19;
TIME 1837.606250;
MOVE Plane26 LastSCAP 42.666667;
TIME 1862.612977;
MOVE Plane23 R21RF2Gatec 109.000000;
TIME 1880.272916;
MOVE Plane26 PLand1 23.496296;
TIME 1897.681421;
MOVE Plane25 ONRun21R 15.000000;
TIME 1903.769213;
MOVE Plane26 PLand2 31.200000;
TIME 1930.788643;
CREATE Plane31 Type2;
PLACE Plane31 ON GaCVM2R21R;
MOVE Plane31 GaCVM2R21R 230.000000;
TIME 1934.969213;
MOVE Plane26 TaW1W 20.000000;
TIME 1935.288859;
CREATE Plane32 Type1;
TIME 1935.288859;
PLACE Plane32 ON AlignPath1;
TIME 1935.288859;
MOVE Plane32 FirstSCAP 173.529412;
TIME 1954.969213;
MOVE Plane26 WT5PPF2Run21R 154.000000;
TIME 1971.612977;
DESTROY Plane23;
TIME 1971.612977;
MOVE Plane25 RollingR21R 22.952258;
TIME 1994.565236;
MOVE Plane25 TakeOffR21R 86.406115;
TIME 1994.565236;
MOVE Plane27 ONRun21R 15.000000;
TIME 2007.370127;
CREATE Plane33 Type1;
TIME 2007.370127;
PLACE Plane33 ON AlignPath2;
TIME 2007.370127;
MOVE Plane33 FirstSCAPa 173.529412;
TIME 2022.834627;
CREATE Plane34 Type2;
TIME 2030.165771;
CREATE Plane35 Type2;
PLACE Plane35 ON GaCVM2R21R;
MOVE Plane35 GaCVM2R21R 230.000000;
TIME 2038.308297;
PLACE Plane34 ON AlignPath1;
TIME 2038.308297;
MOVE Plane34 FirstSCAP 226.923077;
TIME 2039.363271;
MOVE Plane27 RollingR21R 48.541786;
TIME 2064.856099;
CREATE Plane36 Type0;
TIME 2080.971350;
DESTROY Plane25;
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TIME 2087.905057;
MOVE Plane27 TakeOffR21R 90.324779;
TIME 2087.905057;
MOVE Plane28 ONRun21R 15.000000;
TIME 2106.857518;
MOVE Plane28 RollingR21R 43.553386;
TIME 2108.818270;
MOVE Plane32 LastSCAP 47.058824;
TIME 2118.063721;
CREATE Plane37 Type1;
PLACE Plane37 ON GaCVM2R21R;
MOVE Plane37 GaCVM2R21R 230.000000;
TIME 2150.410903;
MOVE Plane28 TakeOffR21R 101.163242;
TIME 2150.410903;
MOVE Plane29 ONRun21R 15.000000;
TIME 2153.935070;
PLACE Plane36 ON AlignPath1;
TIME 2153.935070;
MOVE Plane36 FirstSCAP 157.333333;
TIME 2155.877094;
MOVE Plane32 PLand1 25.915033;
TIME 2161.195614;
MOVE Plane26 R21RF2Gatec 109.000000;
TIME 2178.229836;
DESTROY Plane27;
TIME 2180.899539;
MOVE Plane33 LastSCAPa 47.058824;
TIME 2181.792127;
MOVE Plane32 TaW2WJ 83.000000;
TIME 2227.958363;
MOVE Plane33 PLanda 29.934641;
TIME 2251.574146;
DESTROY Plane28;
TIME 2257.893003;
MOVE Plane33 TaA42A6 30.000000;
TIME 2264.792127;
MOVE Plane32 PPF2Run21R 130.000000;
TIME 2265.231374;
MOVE Plane34 LastSCAP 61.538462;
TIME 2270.195614;
DESTROY Plane26;
TIME 2287.893003;
MOVE Plane33 A6V2Run22L1 270.000000;
TIME 2311.268404;
MOVE Plane36 LastSCAP 42.666667;
TIME 2326.769836;
MOVE Plane34 PLand1 33.888889;
TIME 2346.620454;
CREATE Plane38 Type0;
TIME 2346.620454;
PLACE Plane38 ON AlignPath2;
TIME 2346.620454;
MOVE Plane38 FirstSCAPa 157.333333;
TIME 2353.935070;
MOVE Plane36 PLand1 23.496296;
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TIME 2360.658725;
MOVE Plane34 TaW2WJ 83.000000;
TIME 2377.431367;
MOVE Plane29 RollingR21R 55.688103;
TIME 2377.431367;
MOVE Plane36 PLand2 31.200000;
TIME 2377.822170;
CREATE Plane39 Type1;
PLACE Plane39 ON GaCVM2R21R;
MOVE Plane39 GaCVM2R21R 230.000000;
TIME 2408.631367;
MOVE Plane36 TaW1W 20.000000;
TIME 2433.119470;
MOVE Plane29 TakeOffR21R 83.179608;
TIME 2433.119470;
MOVE Plane30 ONRun21R 15.000000;
TIME 2446.437059;
MOVE Plane32 R21RF2Gatec 109.000000;
TIME 2446.437059;
MOVE Plane34 PPF2Run21R 130.000000;
TIME 2503.953787;
MOVE Plane38 LastSCAPa 42.666667;
TIME 2516.299078;
DESTROY Plane29;
TIME 2527.753511;
CREATE Plane40 Type2;
PLACE Plane40 ON GaCVM2R21R;
MOVE Plane40 GaCVM2R21R 230.000000;
TIME 2546.620454;
MOVE Plane38 PLanda 27.140741;
TIME 2548.712701;
CREATE Plane41 Type0;
TIME 2548.712701;
PLACE Plane41 ON AlignPath1;
TIME 2548.712701;
MOVE Plane41 FirstSCAP 157.333333;
TIME 2555.437059;
DESTROY Plane32;
TIME 2555.437059;
MOVE Plane30 RollingR21R 39.176668;
TIME 2557.332181;
CREATE Plane42 Type1;
PLACE Plane42 ON GaCVM2R21R;
MOVE Plane42 GaCVM2R21R 230.000000;
TIME 2557.893003;
MOVE Plane33 R22LV2Gatec 32.000000;
TIME 2573.761194;
MOVE Plane38 PLandb 27.093333;
TIME 2589.893003;
DESTROY Plane33;
TIME 2594.613727;
MOVE Plane30 TakeOffR21R 112.516452;
TIME 2594.613727;
MOVE Plane31 ONRun21R 15.000000;
TIME 2600.854528;
MOVE Plane38 TaA12A6 20.000000;
TIME 2606.264891;
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MOVE Plane34 R21RF2Gatec 109.000000;
TIME 2606.264891;
MOVE Plane36 WT5PPF2Run21R 154.000000;
TIME 2620.854528;
MOVE Plane38 A6V2Run22L2 350.000000;
TIME 2706.046034;
MOVE Plane41 LastSCAP 42.666667;
TIME 2707.130180;
DESTROY Plane30;
TIME 2708.184526;
CREATE Plane43 Type2;
TIME 2708.184526;
PLACE Plane43 ON AlignPath2;
TIME 2708.184526;
MOVE Plane43 FirstSCAPa 226.923077;
TIME 2715.264891;
DESTROY Plane34;
TIME 2748.712701;
MOVE Plane41 PLand1 23.496296;
TIME 2760.264891;
MOVE Plane36 R21RF2Gatec 109.000000;
TIME 2768.058912;
CREATE Plane44 Type0;
TIME 2772.208997;
MOVE Plane41 PLand2 31.200000;
TIME 2783.768945;
CREATE Plane45 Type1;
PLACE Plane45 ON GaCVM2R21R;
MOVE Plane45 GaCVM2R21R 230.000000;
TIME 2803.408997;
MOVE Plane41 TaW1W 20.000000;
TIME 2823.408997;
MOVE Plane41 WT5PPF2Run21R 154.000000;
TIME 2839.272890;
CREATE Plane46 Type2;
TIME 2848.888506;
CREATE Plane47 Type1;
PLACE Plane47 ON GaCVM2R21R;
MOVE Plane47 GaCVM2R21R 230.000000;
TIME 2869.264891;
DESTROY Plane36;
TIME 2869.264891;
MOVE Plane31 RollingR21R 50.665814;
TIME 2884.127498;
PLACE Plane44 ON AlignPath2;
TIME 2884.127498;
MOVE Plane44 FirstSCAPa 157.333333;
TIME 2919.930705;
MOVE Plane31 TakeOffR21R 107.945282;
TIME 2919.930705;
MOVE Plane35 ONRun21R 15.000000;
TIME 2934.930705;
MOVE Plane35 RollingR21R 58.413653;
TIME 2935.107603;
MOVE Plane43 LastSCAPa 61.538462;
TIME 2970.854528;
MOVE Plane38 R22LV2Gatec 32.000000;
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TIME 2982.057157;
CREATE Plane48 Type2;
PLACE Plane48 ON GaCVM2R21R;
MOVE Plane48 GaCVM2R21R 230.000000;
TIME 2993.344359;
MOVE Plane35 TakeOffR21R 96.557776;
TIME 2993.344359;
MOVE Plane37 ONRun21R 15.000000;
TIME 2996.646064;
MOVE Plane43 PLanda 39.145299;
TIME 3002.854528;
DESTROY Plane38;
TIME 3015.773457;
MOVE Plane37 RollingR21R 26.483426;
TIME 3027.875987;
DESTROY Plane31;
TIME 3035.791363;
MOVE Plane43 TaA42A6 30.000000;
TIME 3041.460831;
MOVE Plane44 LastSCAPa 42.666667;
TIME 3042.256883;
MOVE Plane37 TakeOffR21R 67.118116;
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