M I T   I n t e r n a t i o n a l   C e n t e r   f o r   A i r   T r a n s p o r t a t i o n

MIT Extensible Air Network Simulation (MEANS)

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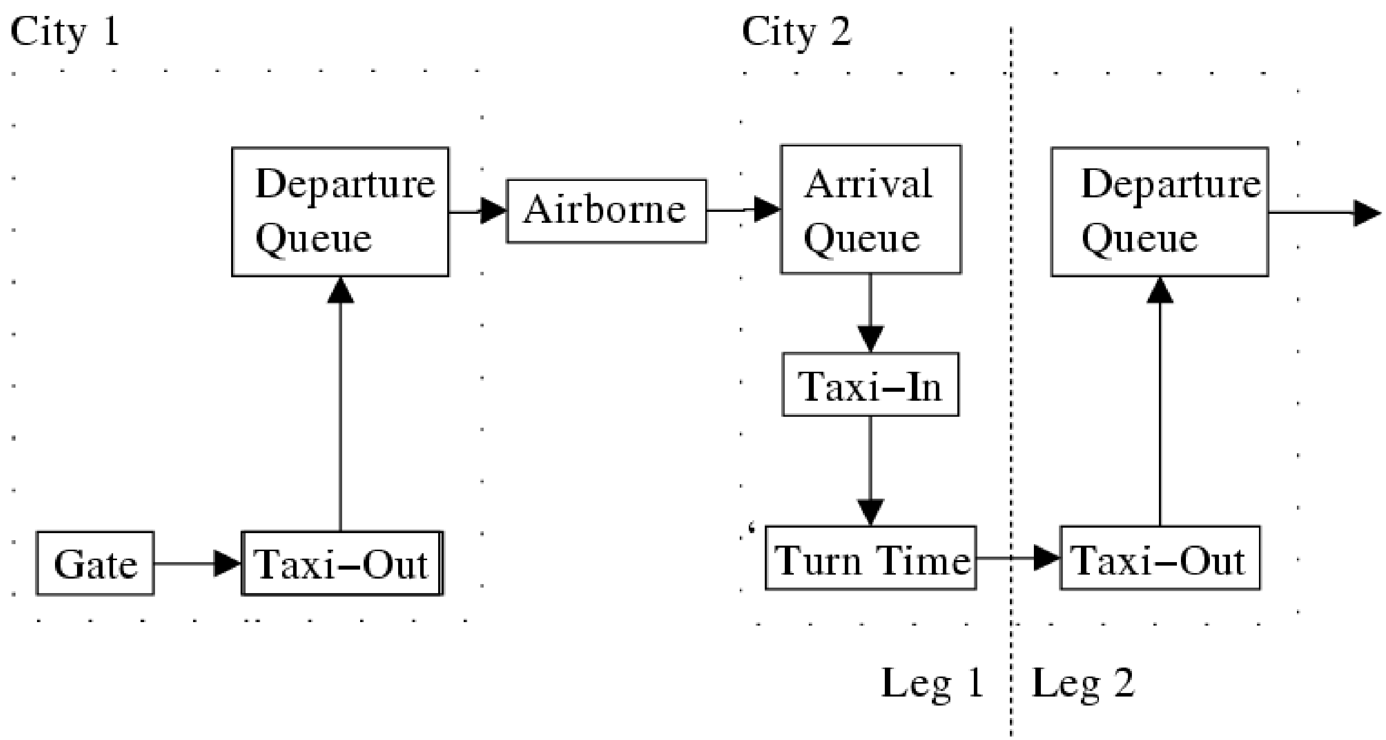
Background

- Development started at the beginning of 2001
  - Developed initially as a tool to evaluate the effect of congestion at a hub airport on the network of an airline
  - Expanded soon thereafter to evaluate ideas related to CDM and airline scheduling
- Continuous improvements
  - GDP model
  - Pareto Frontier generation
  - Weather
  - Airline disruption recovery
  - Human-in-the-loop airline operations interface

Overview

- MEANS is an event-based simulation
- Tracks aircraft through several states
  - Emphasis on ground-based effects
  - Tracks passengers if desired
- Arrival and departure rates at airports are constrained
  - This produces delays which propagate throughout the system
- Multiple runs with same input parameters provide stochastic results

Flight States



Data Sources

- Schedule
  - ASQP database
  - CODAS ETMS database
- Airport Capacities
  - FAA Benchmark Report
  - Theoretical Generation
- Airborne, Taxi, Ground Times
  - Historical Data (ASQP)
- Weather
  - CODAS Weather database

Modules

- Aircraft Turn-Around
- Taxi-Out & Taxi-In
- Airborne
- Tower & TRACON
- Ground Delay
- Airline Operations
- Weather

Aircraft Turn-Around Module

- Determines the amount of time aircraft needs to get ready for departure
- Options
  - Input-output model for turn-around time as a function of arrival delay for each airline and aircraft type (at each airport if desired)
    - Based on MIT M.Eng. Thesis by William Vanderson (supervised by Bill Hall and J.-P. Clarke)

Taxi-Out & Taxi-In Module

- Determines the time aircraft needs to reach departure queue (taxi-out) and gate (taxi-in)
- Options
  - Stochastic distributions for each airport developed from ASQP data
    - Passing behaviour of aircraft included
    - Distributions can be developed for a specific configuration and traffic volume
    - Calculated using algorithm developed by Francis Carr based on technique developed by Idris, Clarke, Bhuva and Kang

Airborne Module

- Determines the flight time between airports i.e. takeoff at origin to arrival queue at destination
- Options
  - Stochastic distributions for each airport pair developed from ASQP and ETMS data
    - Deterministic times can also be used

Tower & TRACON Module

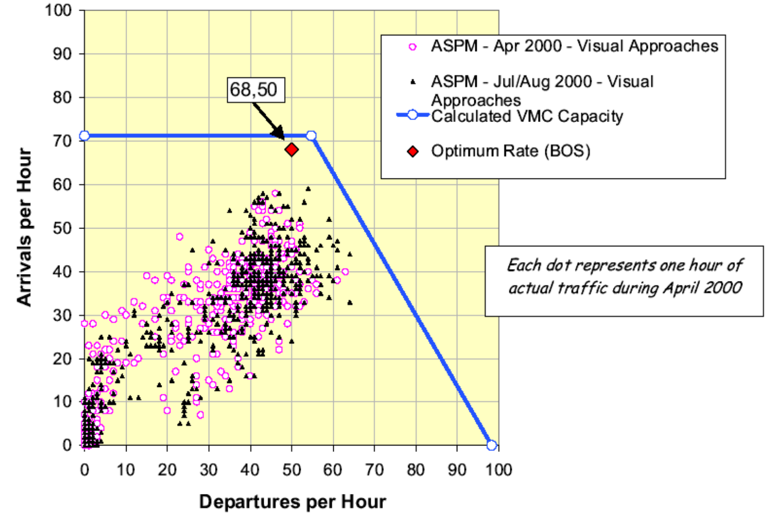
- Sets the capacity of each airport and serves arrival and departure demand (i.e. aircraft in queues)
- Options
  - Arrival and departure rate from historical data
  - Pareto frontier based on historical data
  - Pareto frontier based on simulation
  - Air traffic control agent

Airport Capacity

- Number of operations (arrivals and departures) that can be performed in a specified time period
- What affects airport capacity?
  - Weather Conditions
  - Runway Configuration
  - Fleet Mix
  - Maximum Allowable Arrival Hold Time
  - Individual Controllers

Pareto Frontiers

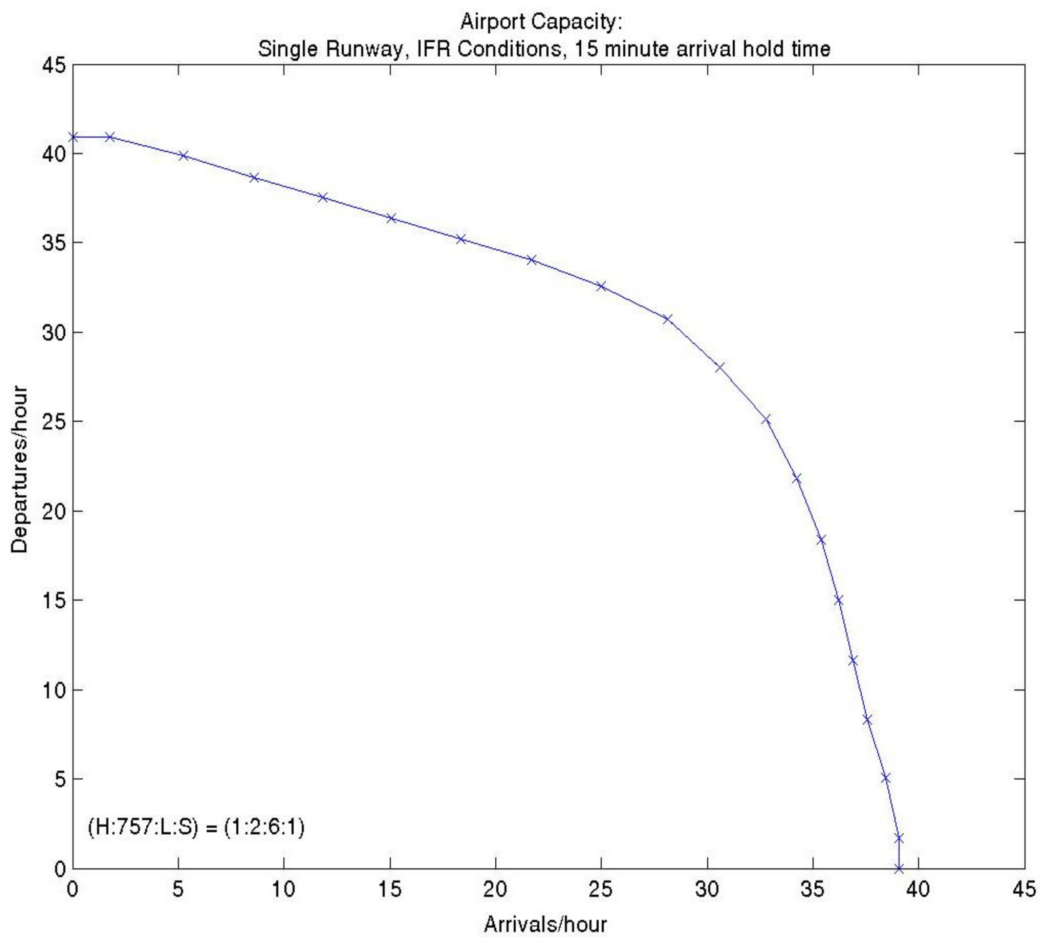
- Curve representing the trade off between two variables (arrival and departure rates)
- Specific Pareto frontier selected based on weather and wind direction
- Operating point based on arrival and departure demand



Pareto Frontiers 2

- Objective: Capture tradeoff between arrivals and departures using shared resources
- Methodology:
  - Aircraft stochastically generated in four weight classes
  - Arrivals on Poisson distribution; departure queue unlimited
  - Spacing based on requirements in FAA 7110.65
  - Optimum sequencing (alternating arrivals and departures) used, contingent on arrival holding requirements

Simulated Pareto Frontier



Status of Capacity Simulator

- Several IFR configurations completed:
  - Single runway
  - Two independent parallel runways
  - Two close parallel runways
  - Two very close parallel
- Other configurations in development
  - Crossing runway under IFR
  - Corresponding VFR configurations

Ground Delay Module

- Manages arrival slots at airports with reduced capacity
- Ground Delay Program (GDP)
  - GDP initiated automatically when predicted capacity falls short by specified amount
  - GDP implemented with simplified Ration-by-Schedule algorithm with compression
  - Module sends airline "agents" assigned slots
  - Module re-assigns slots based on airline cancellations and rescheduling

Airline Operations Module

- Determines flights that should be cancelled and/or rescheduled in response to delays or mechanical failures
- Options
  - Simple airline "agent" cancels all flights delayed over a specified time and push back all departures
  - Human-in-the-loop test subjects make decisions about cancellation and rescheduling of flights
  - "Smart" airline agent determines optimum cancellation and rescheduling strategy based on current situation

"Smart" Airline Agent

- Model incorporates:
  - Information latency
  - Decision making process
- Timing (completed)
  - Stochastic time lags
- Decision Making (under development)
  - Optimum cancellation and rescheduling strategy based on current situation (information available at given time) and impact of decision on airline cost
  - Based on MIT Sc.D. Thesis by Michael Clarke

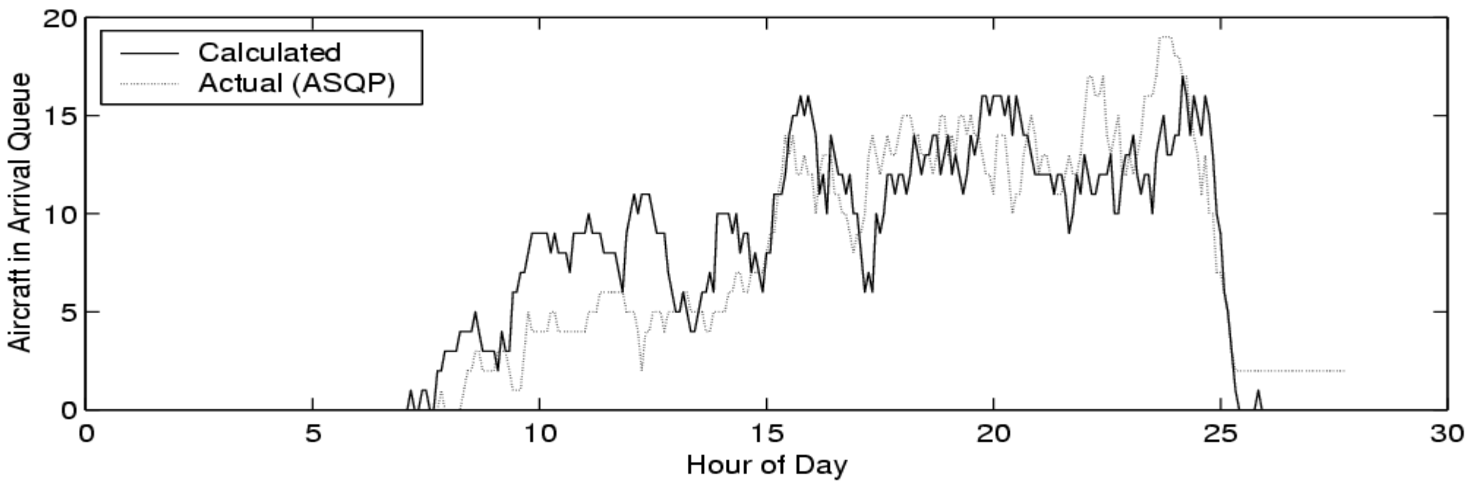
Weather Module

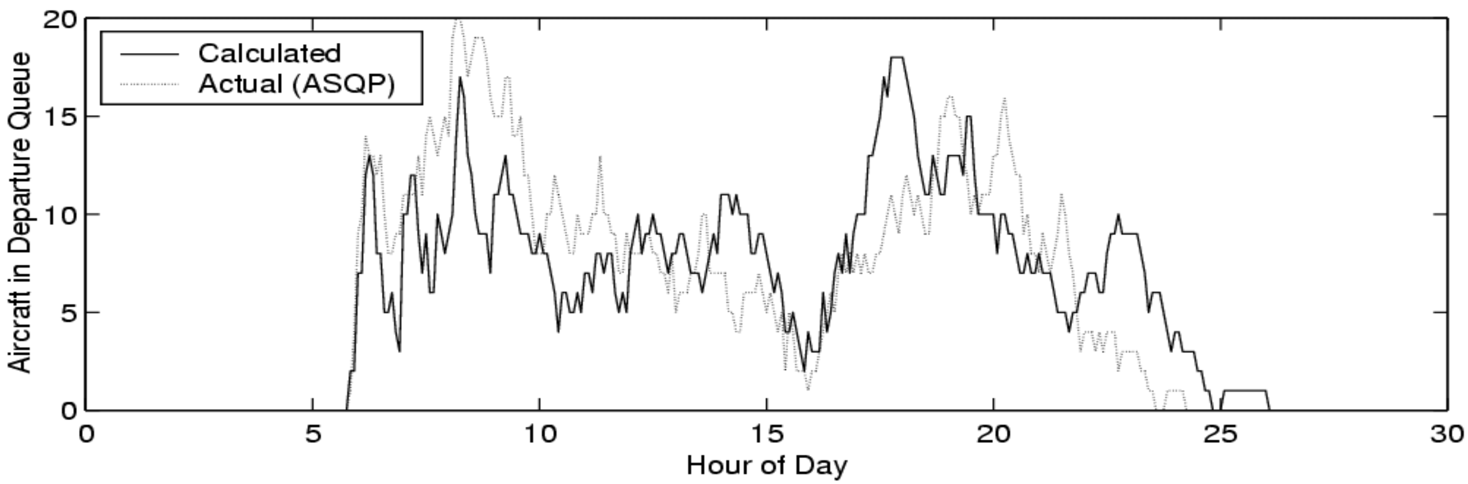
- Determines "observed" and "predicted" weather at each airport
- Options
  - Actual and predicted weather from historical data
  - Markov model of observed weather (under development) and probability distributions for mapping observed weather to predicted weather (development just commencing with help from Lincoln Labs)

Output

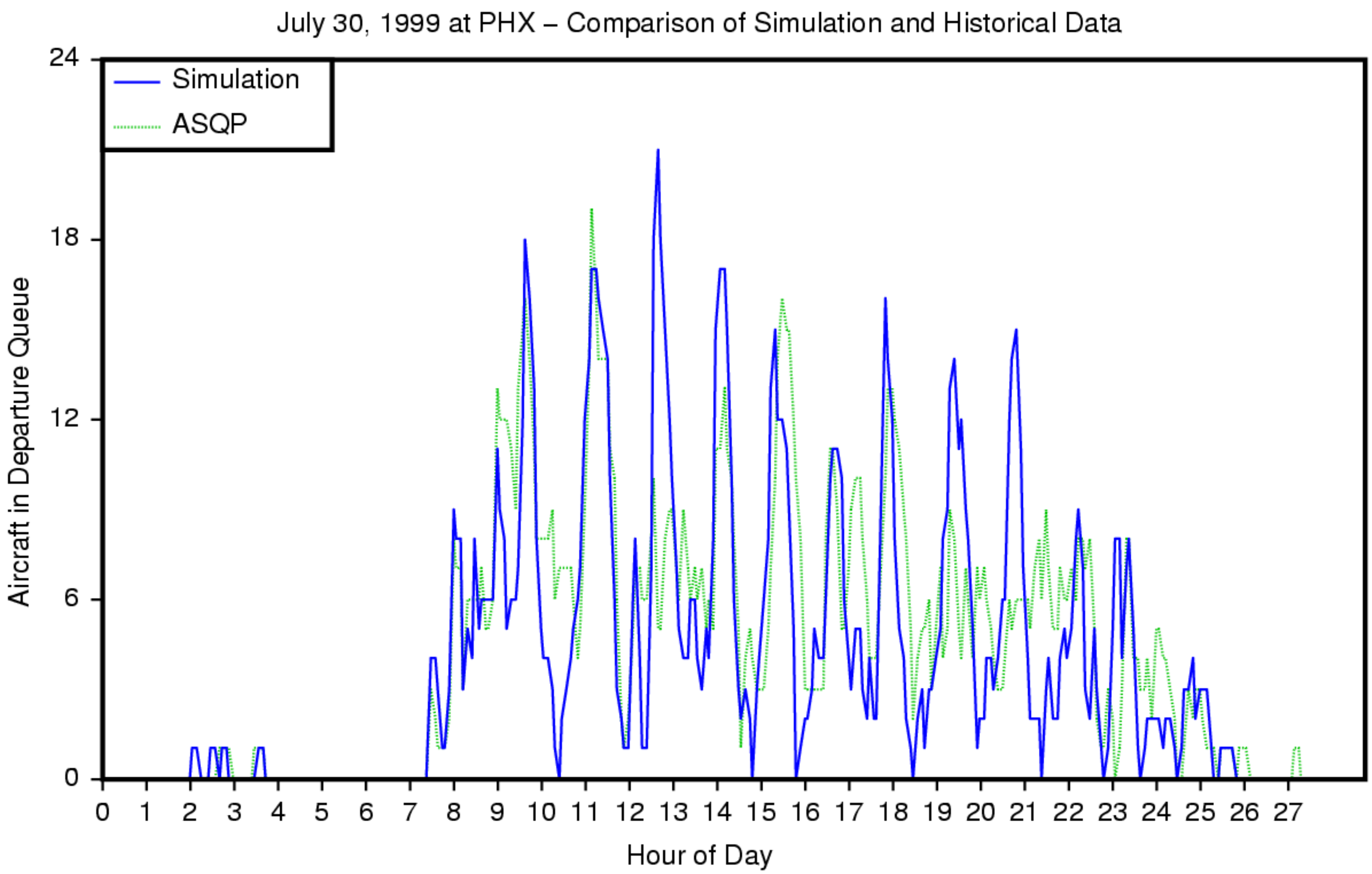
- Detailed results for every flight
- Distilled statistics
  - Delay percentages/averages
  - Cancellations, expected missed connections
  - Direct delay cost to airlines in dollars
- Visualization tools allow examination of bank structure and tracking of delayed flights

Results - GDP at Boston





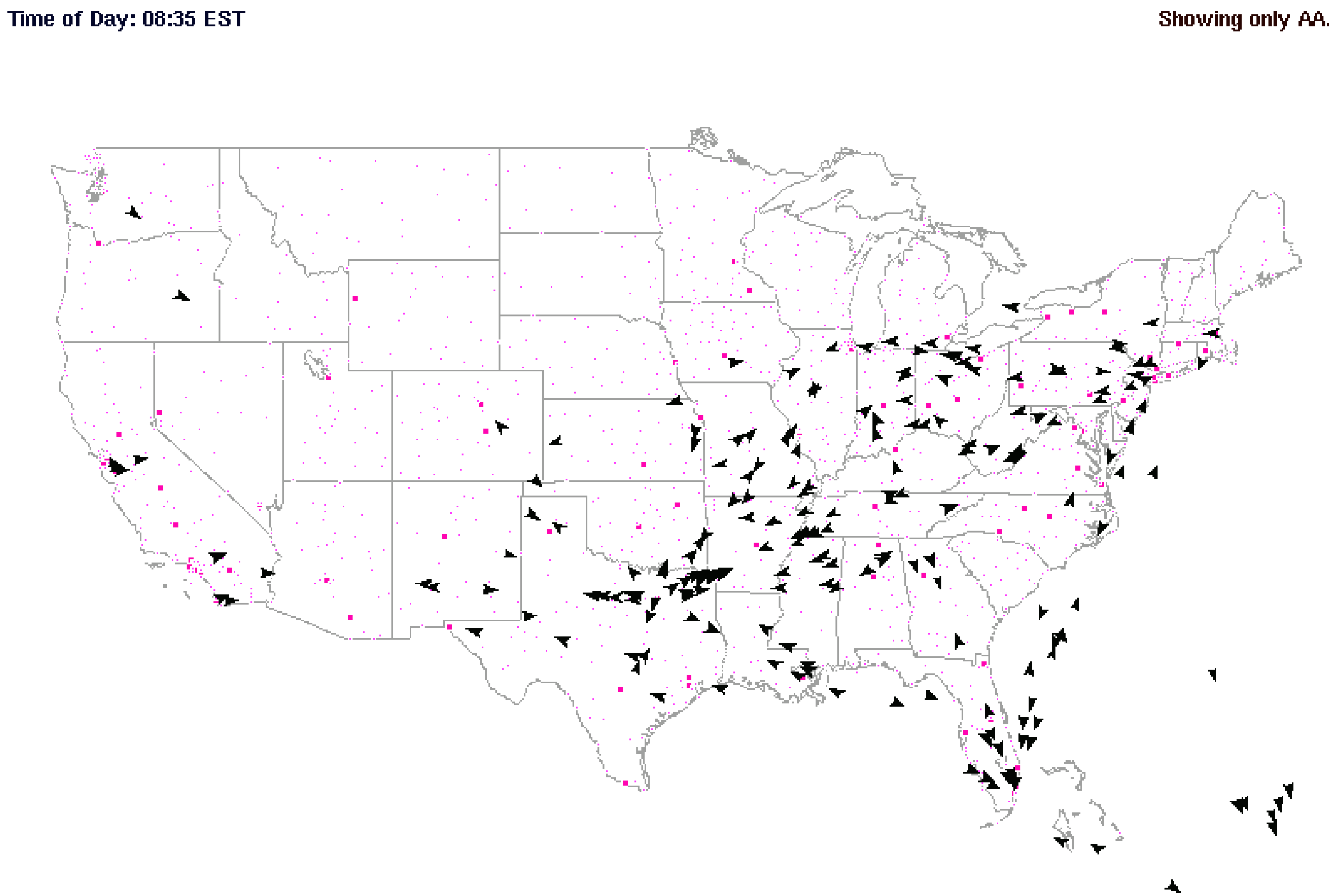
Results - Peak Day at Phoenix



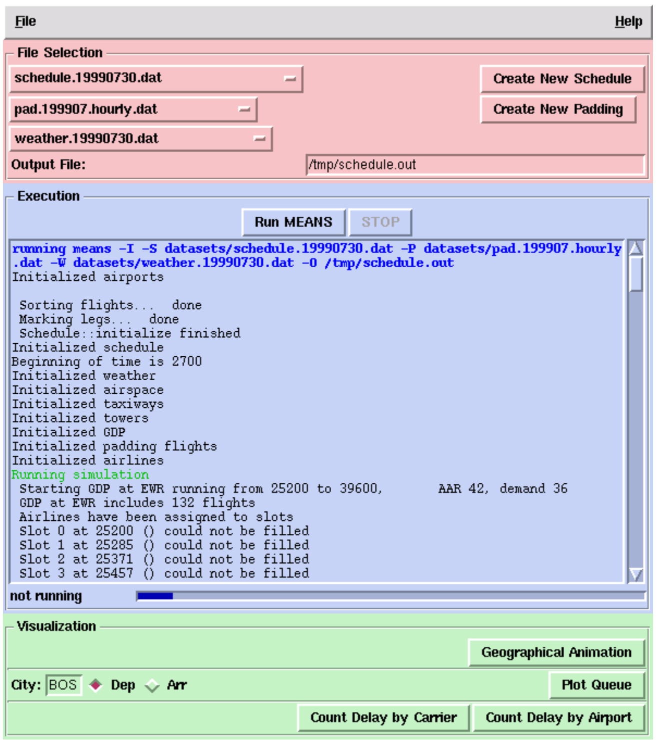
Results - 20% Cancellation

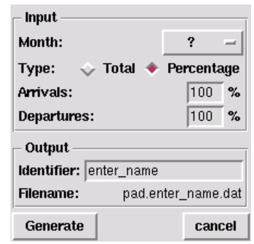
September 17, 1999		September 17, 1999 minus 20%	
Total Systemwide Delay:	**412223**	**Total Systemwide Delay:**	**181008**
carrier	**delay(min)**	**carrier**	**delay(min)**
AA	29485	DL	14528
UA	28215	NW	13889
DL	25251	UA	12190
NW	21957	AA	11121
...		...	
city	**delay(min)**	**city**	**delay(min)**
LAX	54944	MIA	15803
DFW	45049	MSP	14323
MIA	32586	DFW	12617
MSP	26974	DTW	10762
DTW	21407	CVG	10414
CVG	19833	SEA	9157
ORD	18700	STL	7757
SEA	17125	ORD	7274
STL	16851	SFO	7184
LGA	15799	PIT	6557

Visualization Example



Graphical Interface





- Previous command-line interface still available when desired

Other Features

- Remote-Module Interface
  - Allows other sites to provide a module for MEANS without needing to release source code
  - Allows collaborative development in incompatible programming languages or operating systems
  - Can also be used to let a human operate certain components as the simulation runs
- Stochastic Modelling Framework
  - Framework to run MEANS repeatedly as a Monte Carlo simulation and collect results from each run
  - Tools to extract probability distributions of interesting parameters from these data

MEANS Team

- Prof. John-Paul Clarke
- Terran Melconian (Chief Engineer)
- Elizabeth Bly '03 (Airport & TRACON)
- David Smith '03 (Weather)
- Fabio Rabbani, S.M. '04 (Airline Operations)
- Georg Theis, M.S.T. '04 (Ground Delay)