Aviation Studies Program

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Technology Assessment

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ASAC Home Page: http://www.asac.lmi.org

LMI

Advanced Systems and Resource Analysis

Agenda

- Overview of Work Program
- Summary of Current Studies
- Airline Investment Issues

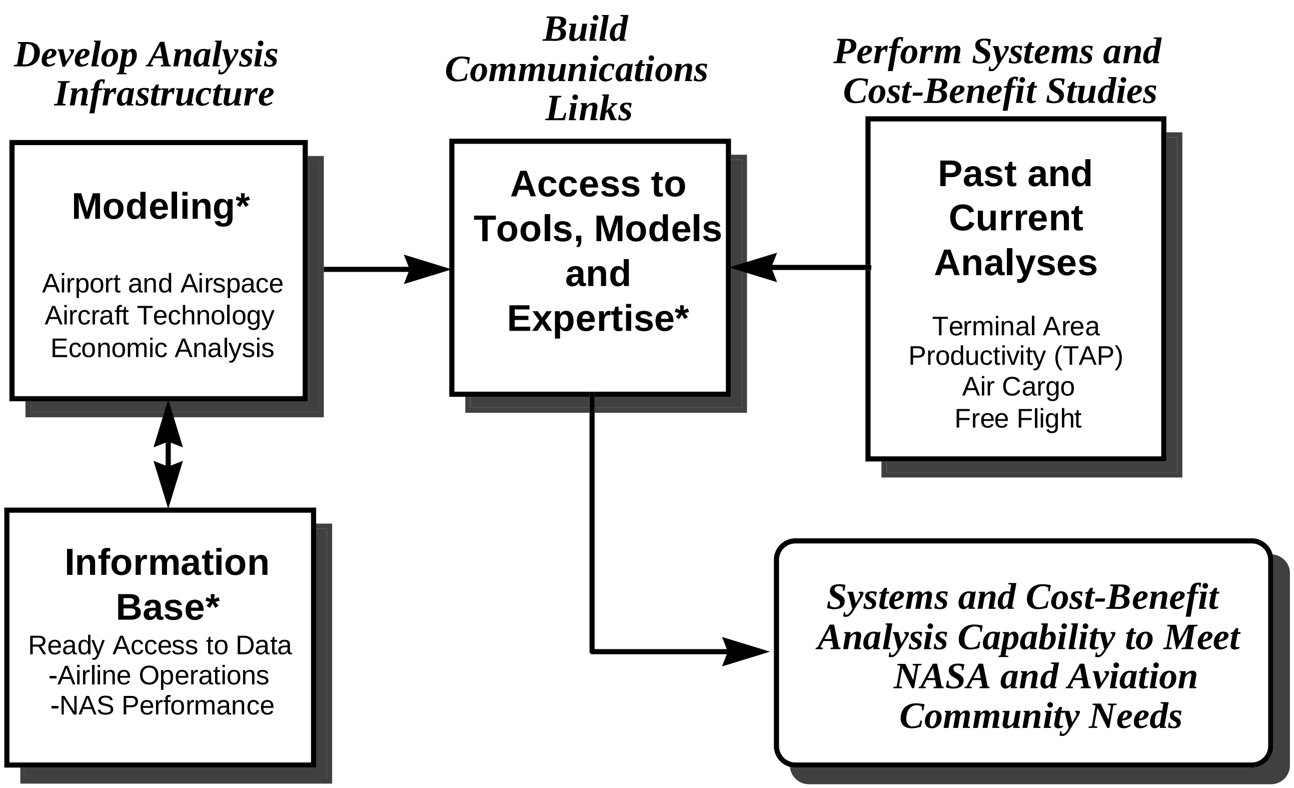
About LMI

- Founded in 1961, operates a Federally-Funded Research and Development Center and a Center for Public Administration
- Retains about 260 professional staff members, located in McLean, Virginia
- Conducts studies and analyses for numerous Federal agencies, including:
  - NASA FAA
  - DOD Postal Service
  - EPA HHS

Technology Assessment

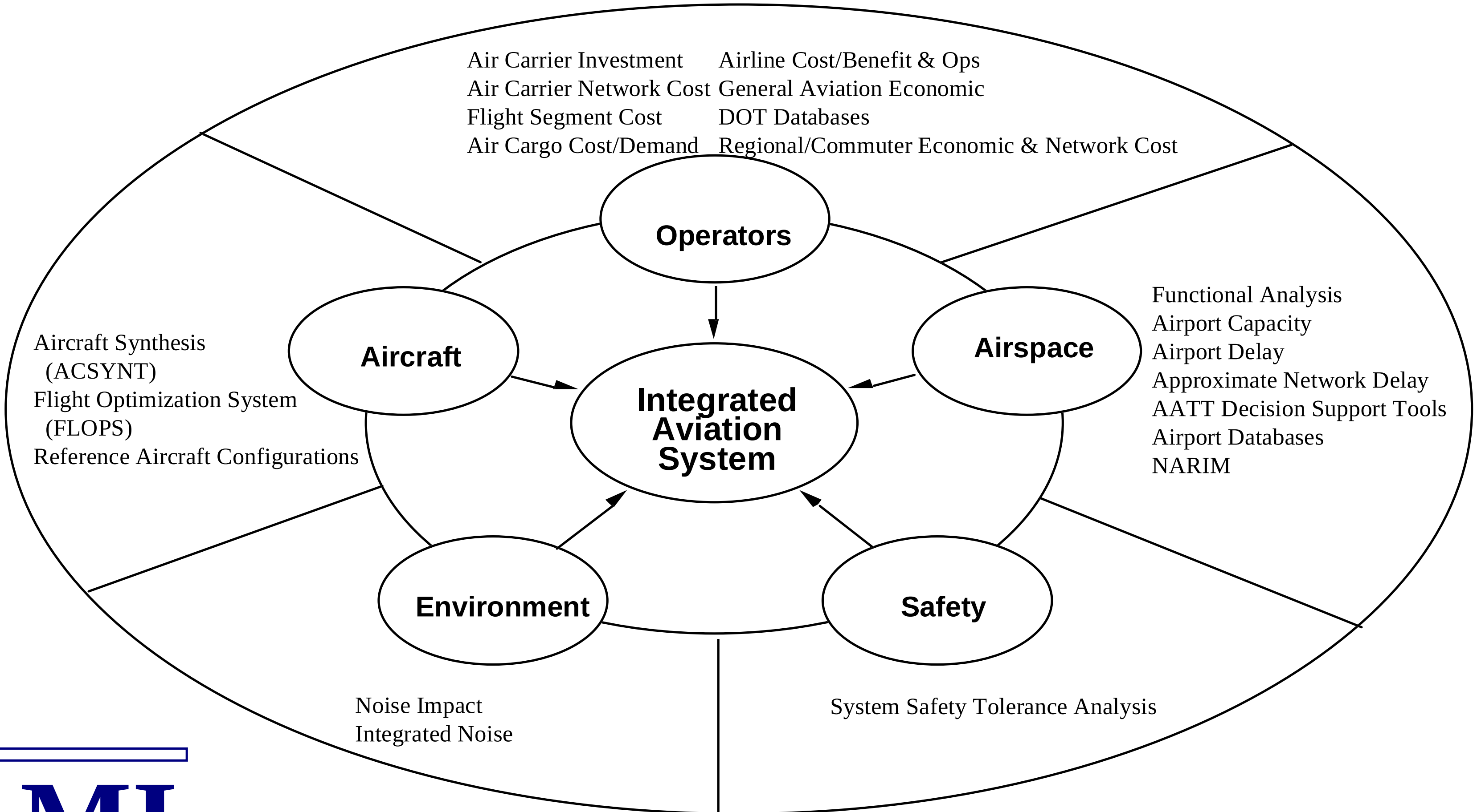
- Supporting the NASA Aeronautics research program since 1993
  - staff of 18 full-time LMI employees, suplemented by several consultants
  - Diverse skills, including
    - economics and finance (5)
    - systems engineering (2)
    - mathematics and OR (6)
    - computer science (4)
    - engineering (2)
  - Teaming arrangements with other organizations, including MIT, Charles Stark Draper Laboratory, CSSI, and others

Integrated Development & Analysis Approach



* ASAC components

Where We Stand Today



Applications of ASAC

- Preliminary National-Level Benefit Assessment of NASA AST Elements
- Aeronautics Enterprise Scenario-Based Strategic Planning
- Terminal Area Productivity (LMI and FAA)
- AATT Decision Support Tools Evaluation (LMI)
- Dallas-Ft. Worth CTAS Operations Safety Evaluation (LMI)
- Aircraft and Airport Noise (LaRC)
- Program Planning and Evaluation (LaRC)
- Rotorcraft Ops Concepts (Boeing-GRA)
- Aircraft Noise (P&W)
- Optimal Flight Routes (UAL)

Air Traffic Management Work Program

- Aviation System Analysis Capability (ASAC) Development (NASA Langley)
  - integrated suite of models and databases to evaluate the impacts of advanced technologies on the air transportation system
- Terminal Area Productivity (NASA Langley)
  - evaluate the capacity impacts and economic benefits of the NASA TAP program (wake vortex detection, landing and taxi aids, closely spaced runways, CTAS/FMS integration)
  - Evaluates TAP effects at 10 major US airports (BOS, DTW, ATL, DFW, SFO, LAX, JFK, EWR, LGA, and ORD)

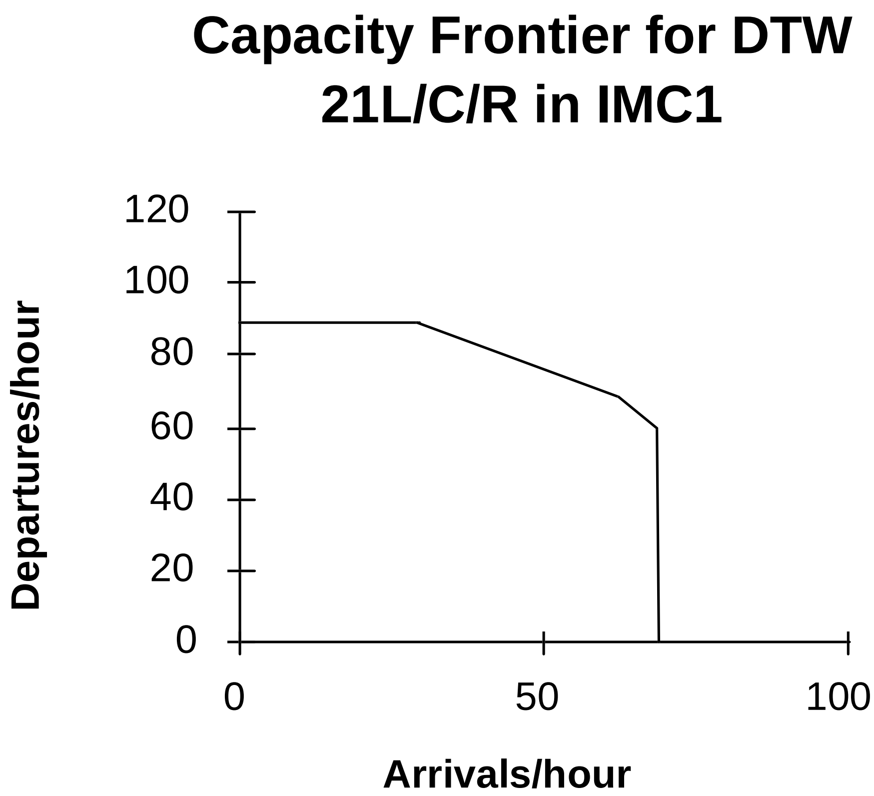
Air Traffic Management Work Program-II

- Advanced Air Transportation Technology (NASA Ames)
  - Benefits analysis of AATT decision support tools
    - high level study of bottlenecks and specific DST analyses
    - develop analysis framewrk for conducting cost-benefit analyses througout the AATT program
  - AATT program evaluation metrics
    - evaluate AATT program metrics, FAA and industry objectives
  - Safety analysis of DFW
    - build framework for evaluating safety effects of ATM automation

Airport Capacity and Arrival Delays

- Developed to analyze NASA Terminal Area Productivity (TAP) benefits
- Parameterized capacity models for 10 airports
- Configuration selection model for each airport (computes delay metric)

A Capacity Frontier



Technology Related Parameters

- Runway occupancy times and variation (by WX)
- Miles-in-trail separations (by MC)
- Measures of uncertainty
  - position
  - velocity
- Wake vortex hold time
- Length of common path

Parameters Unaffected by Technologies

- Wind uncertainty
- Traffic mix
- Local operating strategies
- Departure runway occupancy

Capacity Model Philosophy

- Controller oriented
  - Minimum separation along common path
    - diagonal separations, faster or slower in trail
  - Single occupant of runway
    - wake vortex holds, crossing runways
- Controller assigns separation to anticipate future positions
- Separation includes hedge against uncertainty
  - separation = mean + n*std.dev

Outputs

- For each configuration and each weather condition, a set of (arrival rate, departure rate) points on the capacity frontier
- Outputs verified with controllers
- Model reviewed and approved by MIT

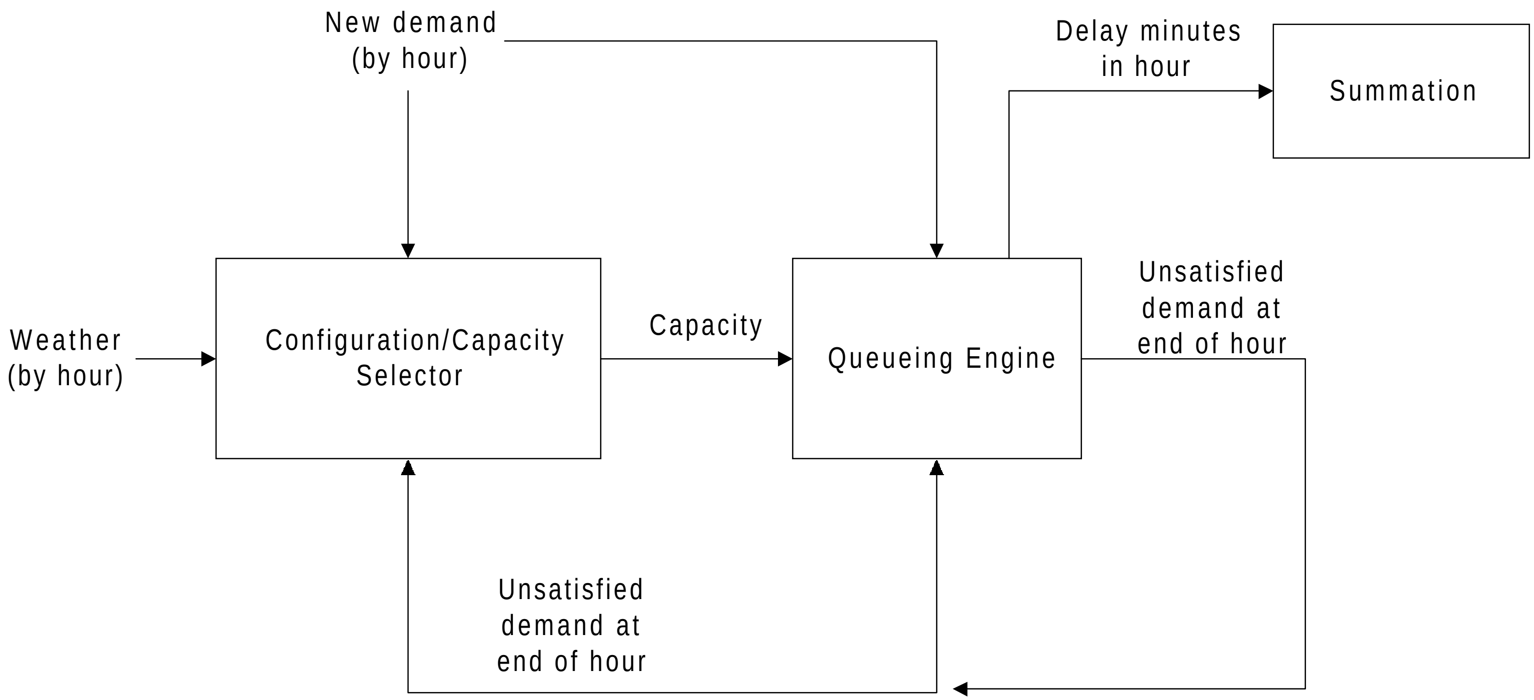
Delay Model

- Compute a delay metric for given set of capacity curves
- Difference between two cases estimates operational arrival delays incurred or avoided
  - Not like ASQP (which compares actual arrival time vs. scheduled arrival time)

Delay Model Philosophy

- Queueing (statistical) model
- Measures imbalance between capacity and demand
- Does *not* measure where delay occurs (not a simulation model)
- Can process 35 years of hourly wx in 20 minutes on 486 PC

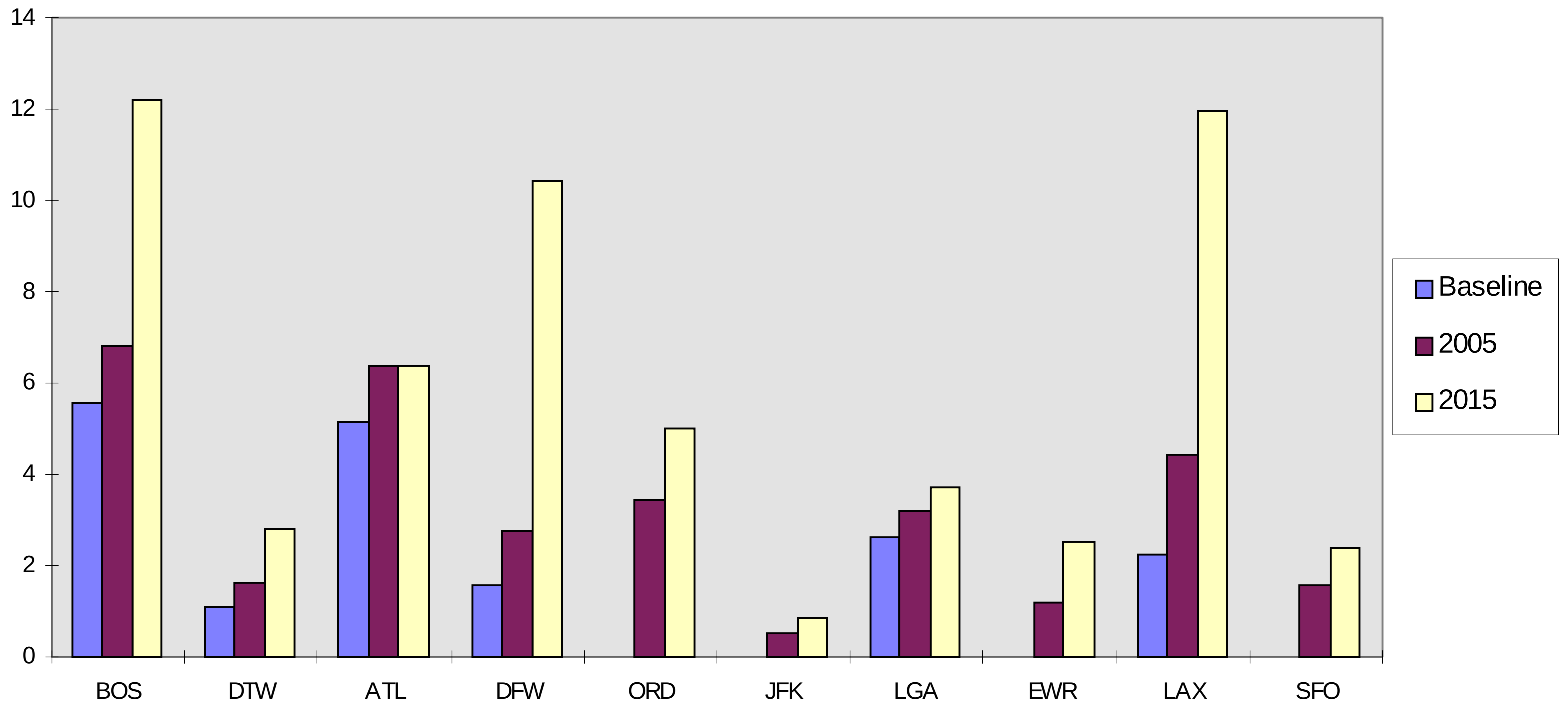
Analytical Description



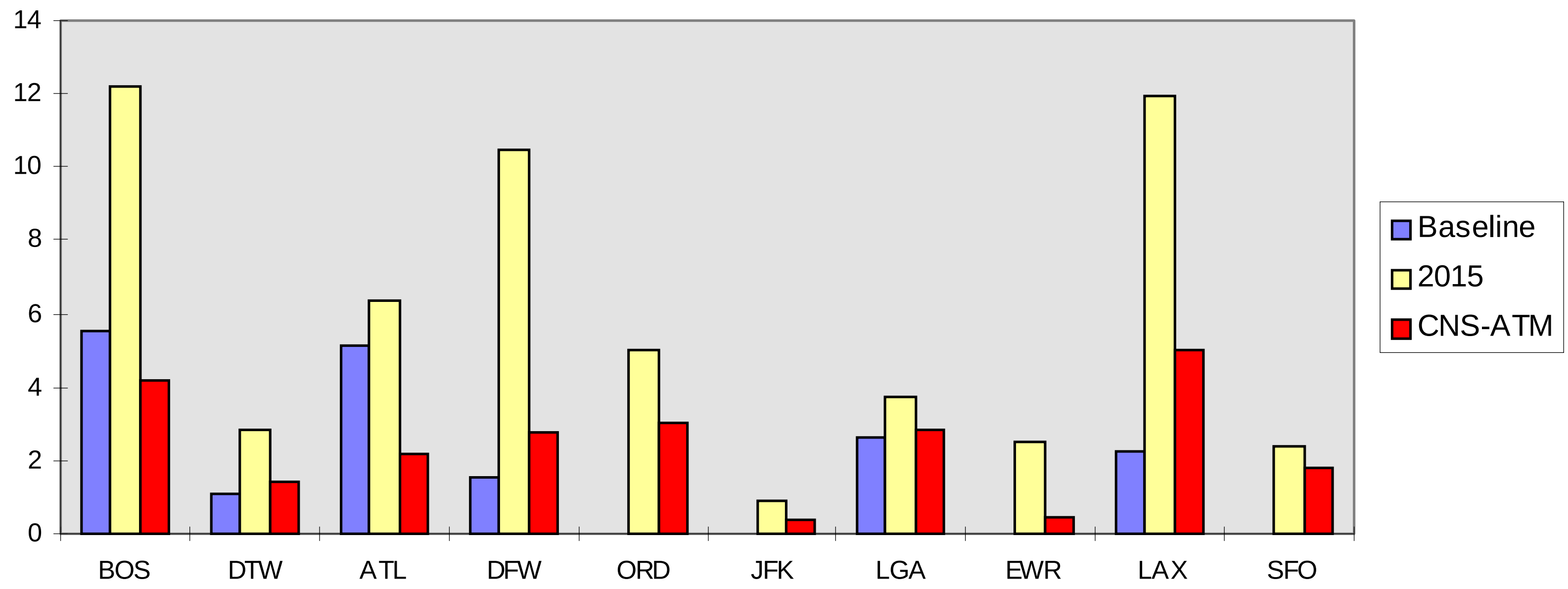
Inputs

- Configuration capacities for different weather conditions (output from Airport Capacity Model)
- Actual weather data (wind, ceiling, visibility, precipitation) for 35 years
- Traffic inflation over baseline year
  - From FAA Terminal Area Forecast, by year
  - Truncated for some airports
  - Arrivals/departures by hour based on historical OAG data

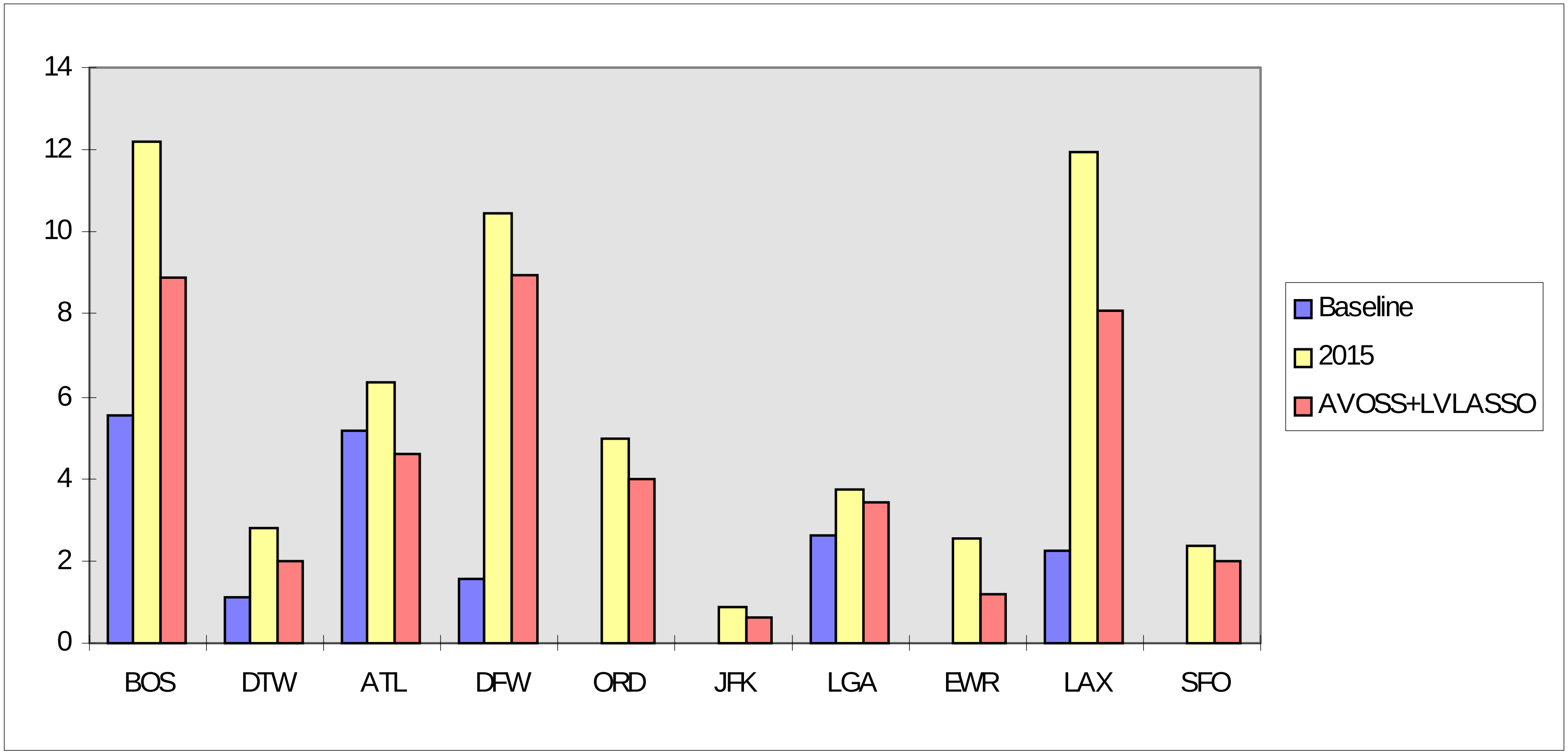
Airport Delays
Do Nothing Scenario



Airport Delays
CNS-ATM Integration



Airport Delays
AVOSS and LVLASO



ATM Modeling at LMI

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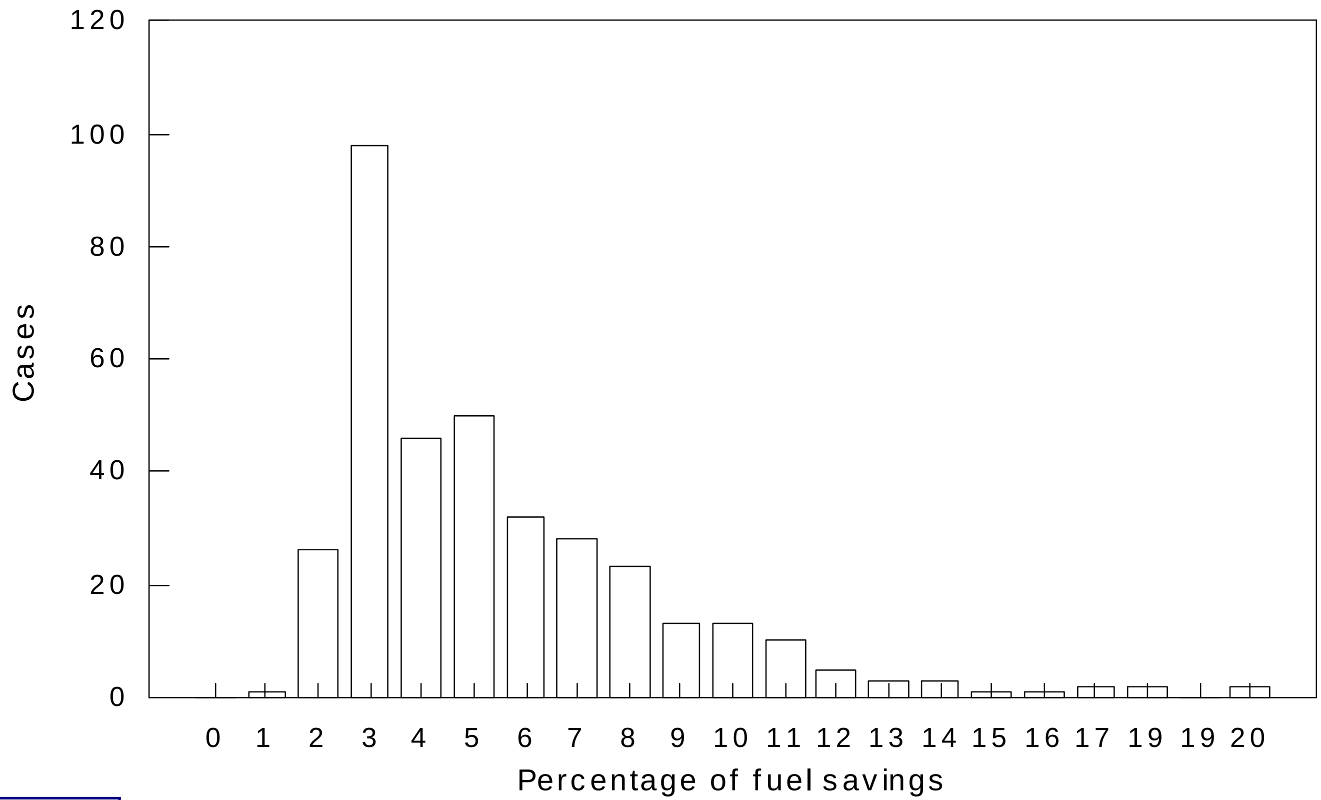
Some Recent Work

- Free flight study
  - What improvements in airlines’ fuel-time trade space would operations on 4-D optimal trajectories give, in comparison with operations on FAA preferred routes?
- Decision support tools for ATM
  - What delays may be expected early in the new century, and how much can DSTs reduce them?

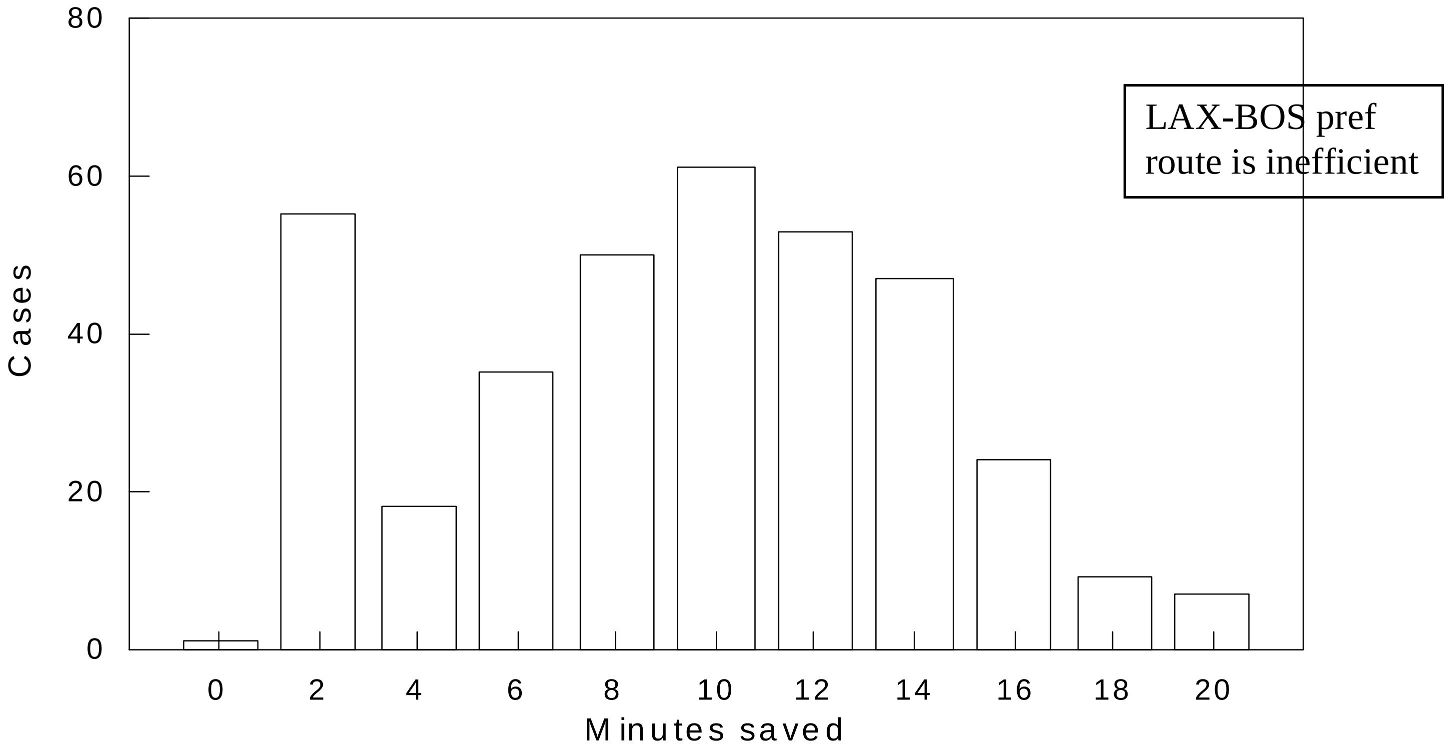
Free Flight Study

- For 362 days of 1995, compared fuel burns and block times on optimal trajectories {lat(s), long(s), alt(s), M(s)} with burns and times on FAA preferred routes
  – Dispatch policy: minimum fuel, with maximum block time constraint

Fuel Savings, BOS-LAX



Time Savings, LAX-BOS



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Summary of Free Flight Results

- 4-D optimal routes give 3 to 7 percent fuel savings, and as much as 15 minutes' block time reduction on long routes
- The fuel savings are fragile: 15 minutes' loiter in terminal airspace at inefficient altitudes/airspeeds can devour them

Decision Support Tool Study

- Identify the potential for improving NAS system performance with NASA-developed Decision Support Tools (DSTs)
- Consider the NAS in 2005

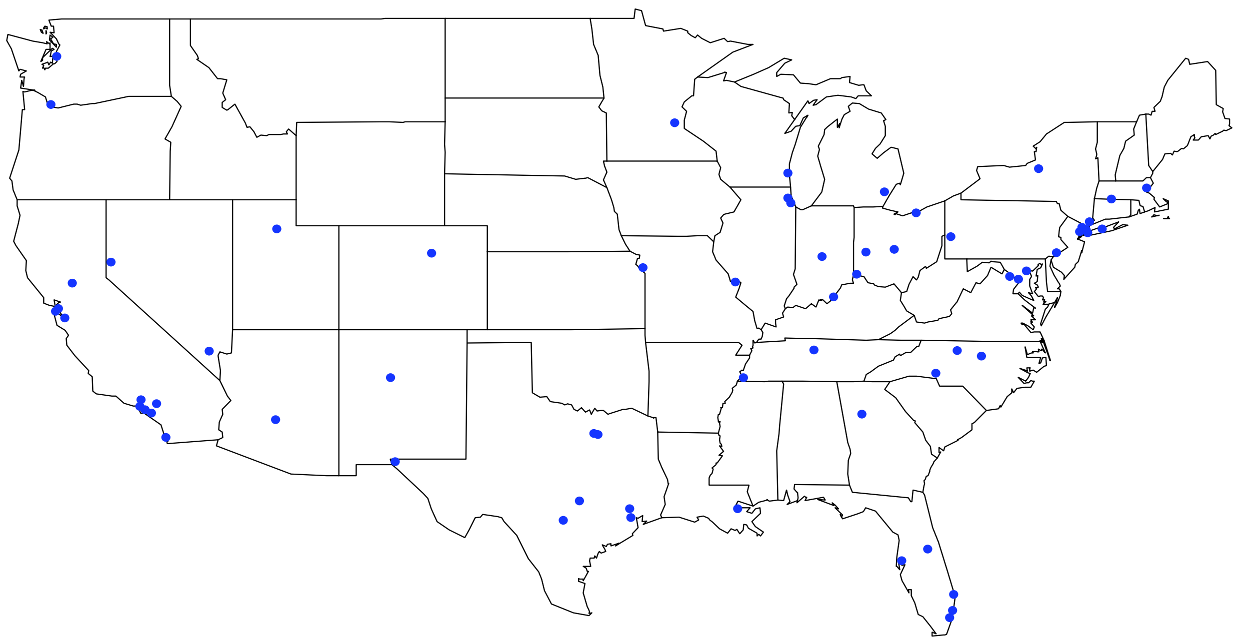
Tools

- Economic models
  - Cost-per-minute of in-flight and ground delays
- Queuing network model of the NAS, **LMINET,** developed for NASA by LMI
  - Links queuing models of individual airports…
    - Via queuing models of TRACONs and ARTCC sectors
    - User may choose sectorization and routes

Tools (continued)

- **FAM**: simulation model of TRACONs and ARTCC sectors, developed for NASA by LMI Used to:
  - analyze task loading
  - support changes to LMINET parameters modeling DST impacts
- Optimal route generator

LMINET Airports



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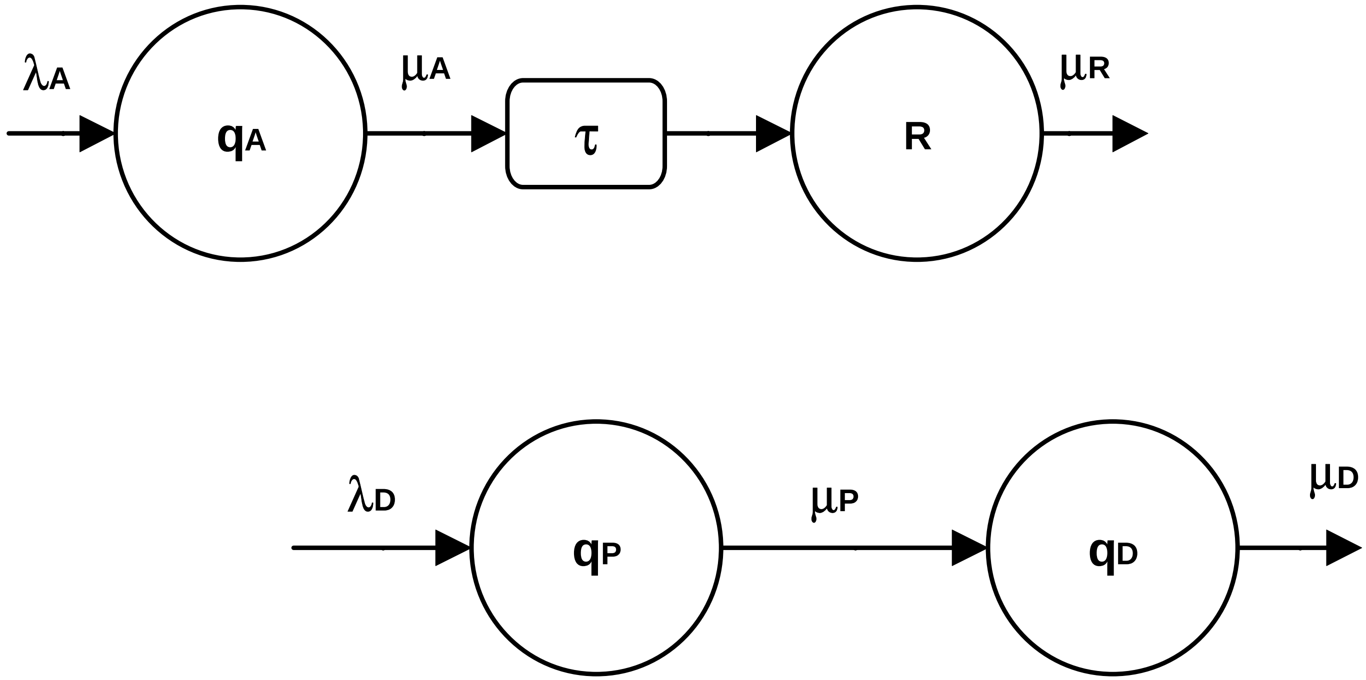
Queuing Model for Airport Delays



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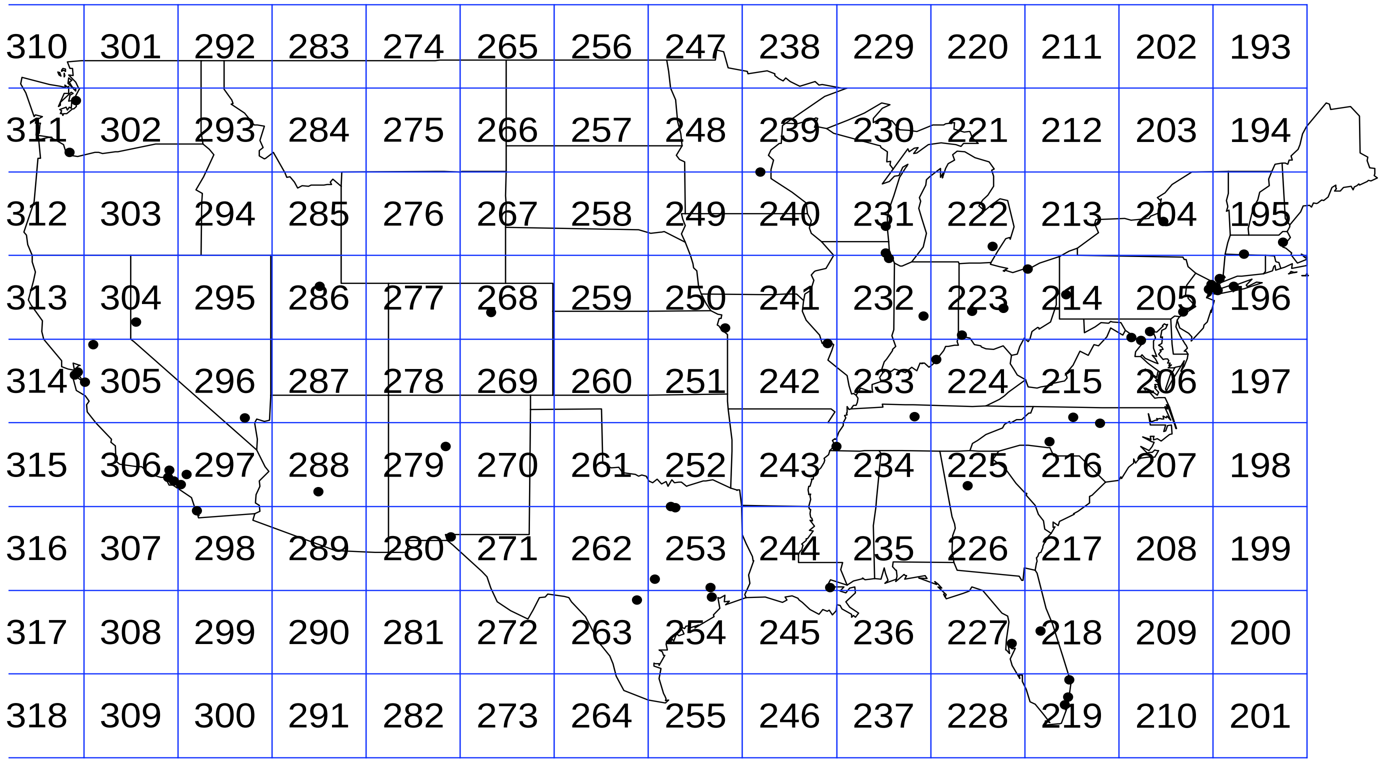
Sector Model

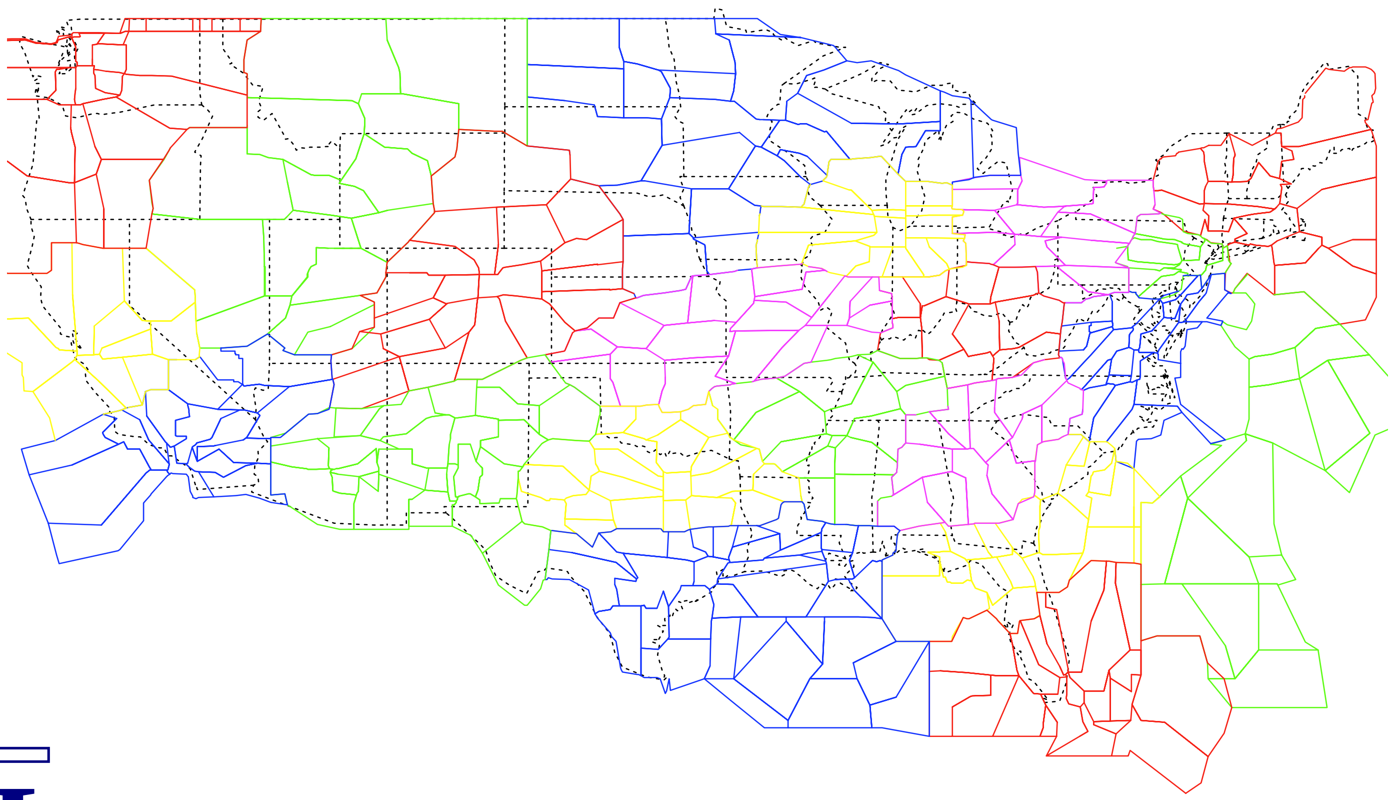
- Models an enroute or TRACON sector as M/D/N or M/Ek/N/(N+q) queue
- Sector model developed with inputs and reviews from
  - FAA Command Center, Herndon, VA
  - Denver ARTCC
  - Denver TRACON
- Calibrated with ETMS data

LMINET Area Sectors

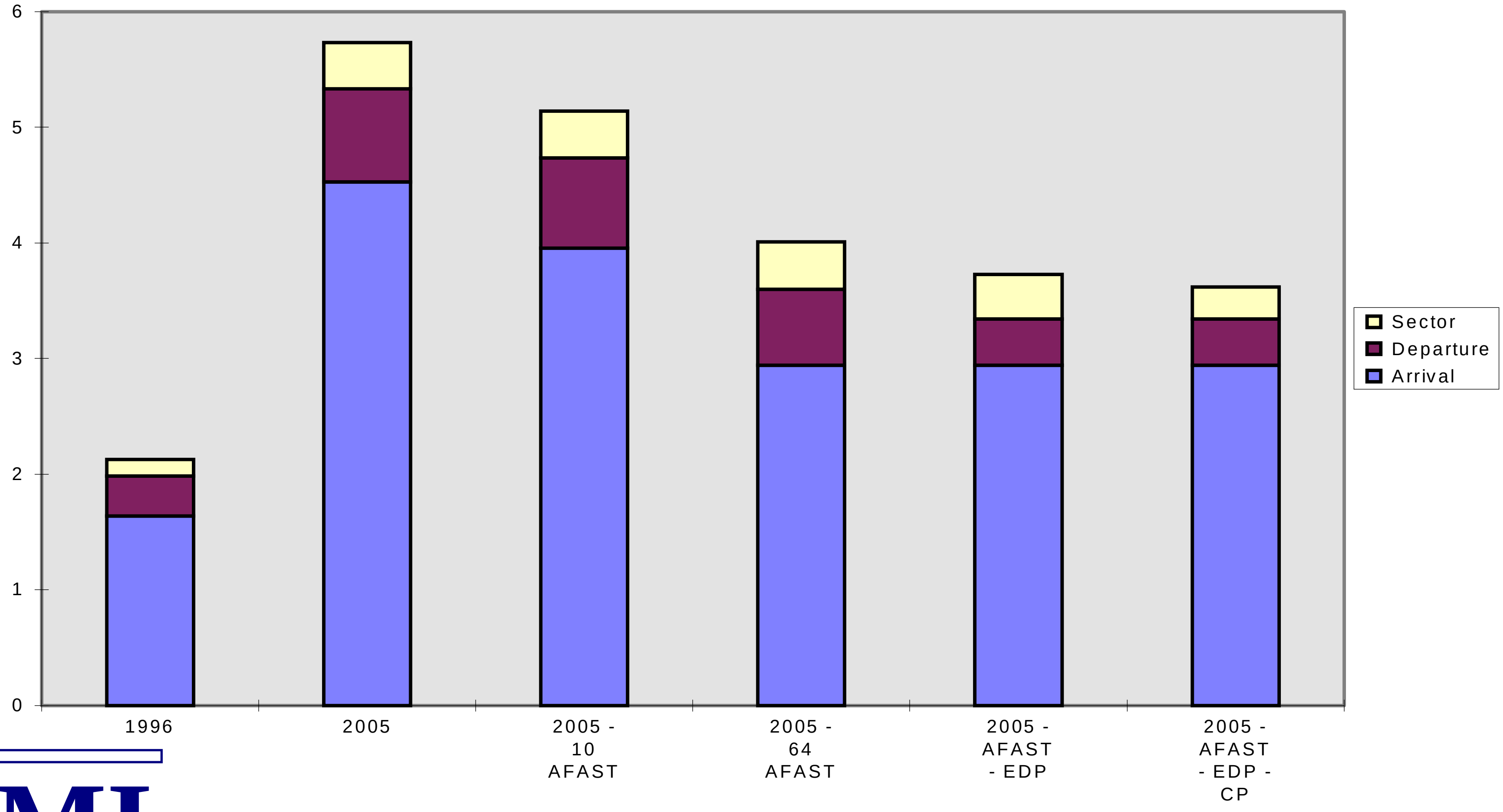


Airports and enroute sectors, 64-Airport LMINET

LMINET FAA Sectors



Early Results



Air Carrier Investment Model

Briefing and Demo to

ASAC Workshop

August 13, 1997

Earl Wingrove

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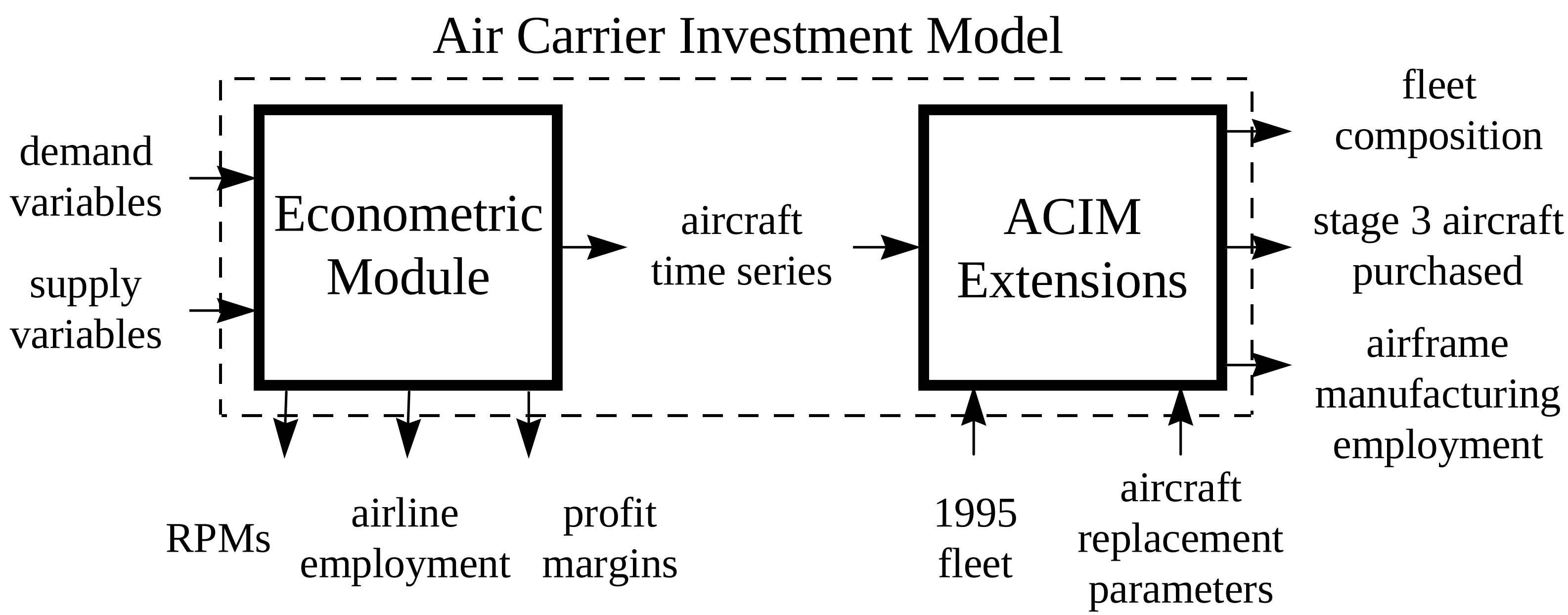
Advanced Systems and Resource Analysis

Purpose

- Develop a parametrically based model that links airline operations and investments in aircraft with emerging NASA technologies

- The model also must provide a mechanism for incorporating air travel demand and profitability into the airlines' investment decisions

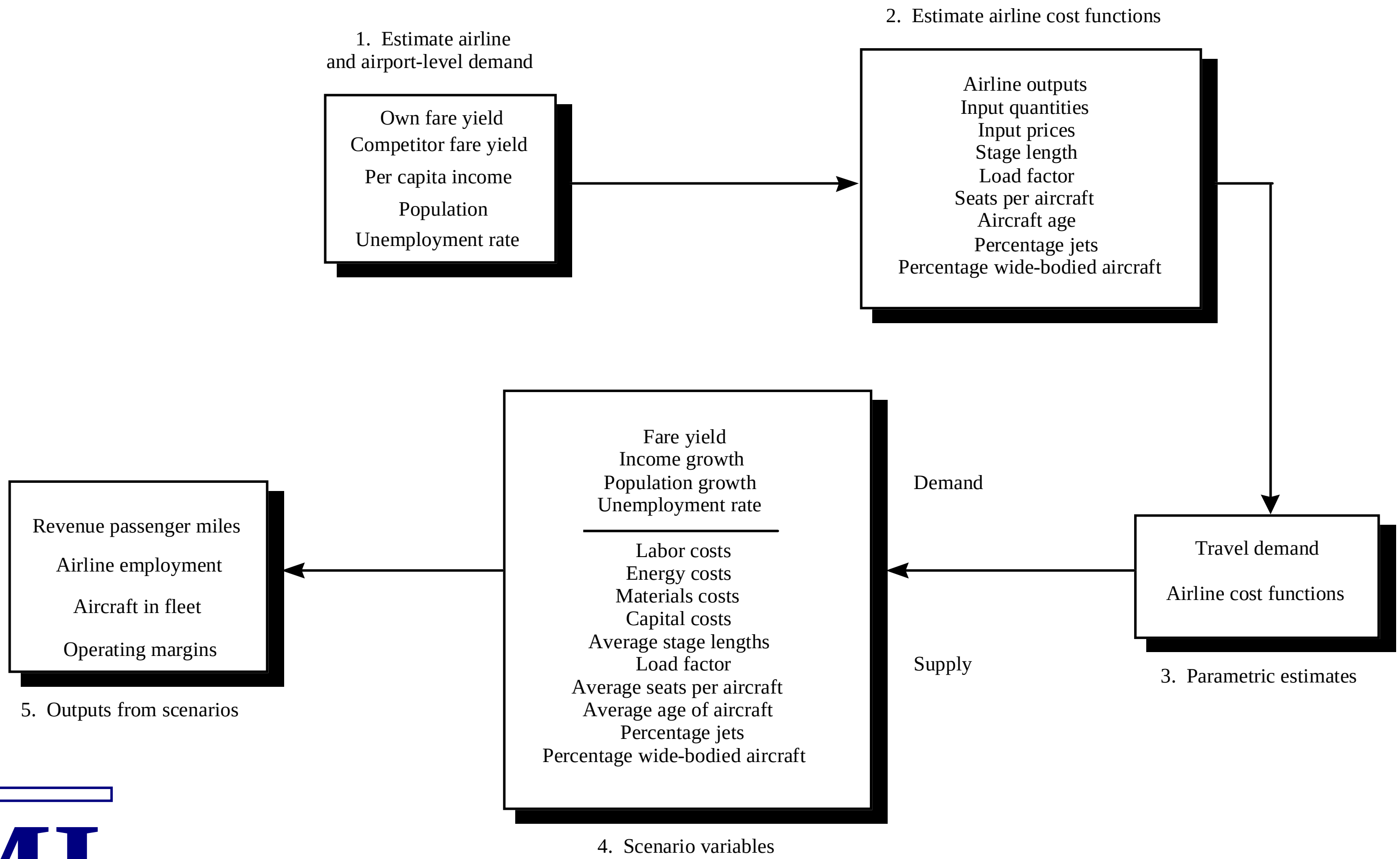
Schematic


Air Carrier Investment Model
demand variables
supply variables
Econometric Module
aircraft time series
ACIM Extensions
fleet composition
stage 3 aircraft purchased
airframe manufacturing employment
RPMs
airline employment
profit margins
1995 fleet
aircraft replacement parameters

Inputs

- Key inputs to ACIM:
  - Demand variables such as fare yield, per capita income, population, and the unemployment rate
  - Supply variables such as output quantities, factor costs, and network/fleet characteristics
  - Aircraft replacement parameters such as acquisition costs, real interest rates, retirement rules, and worker productivity

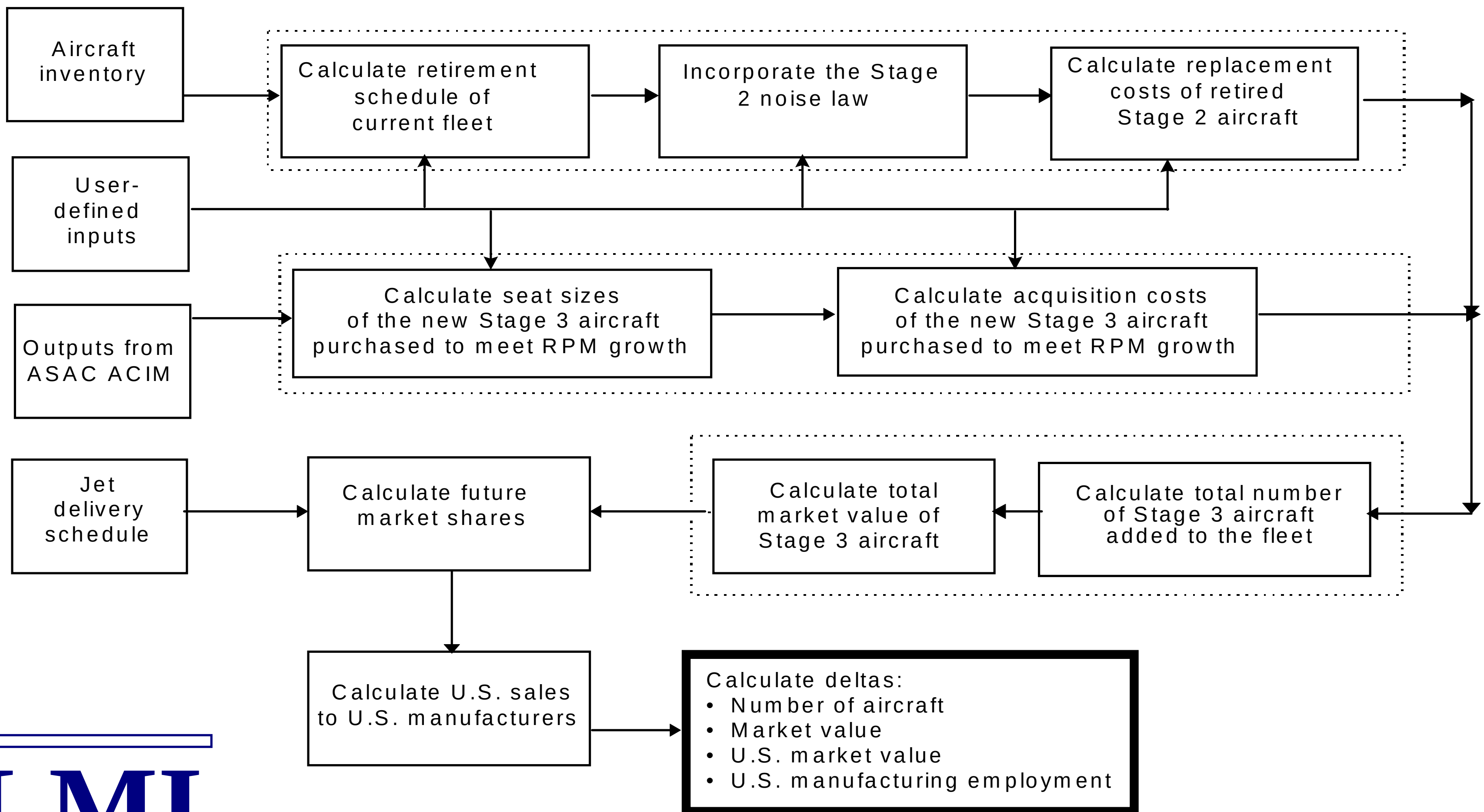
Derivation of Econometric Module



Demand Variables

Variable	Name	Coefficient	T-ratio
Own fares	LNAVEOWN	–1.165	–46.00
Competitors' fares	LNAVEOTHER	0.095	1.83
Per capita income	LNPCI	1.334	8.33
Population	LNPOP	1.228	10.64
Unemployment rate	LNUNRATE	–0.121	–4.63

ACIM Extensions



Outputs

- Time series of:
  - air travel demand (in RPMs)
  - number of airline workers
  - number of aircraft in the fleet
  - airline profitability (operating profit margins)
- Composition of the fleet by seat-size category and year (1995 to 2015)
- Sales to U.S. air carriers and work years of employment generated at U.S. airframe manufacturers
- Results were validated through comparisons with Boeing and FAA forecasts

Baseline Forecast

Variable	Boeing[a]	FAA[b]	LMI
Revenue passenger-mile (RPM) growth	4.74%	4.36%	4.50%
Absolute RPMs (billions) in 2005	888.5	834.1	855.6
Growth in number of aircraft	3.20%	3.05%	2.69%
Absolute number of aircraft in 2005[c]	5,332	5,537	5,451

Note: The Boeing, FAA, and LMI figures for number of aircraft in the 1995 fleet were 3,890; 4,100; and 4,179 respectively.

[a]The Boeing figures are an amalgamation of forecasts from the 1993 through 1996 editions of the *Current Market Outlook*. If forecasts from multiple years were available, preference was given to the latest edition. Additionally, preference was given to U.S.-specific forecasts; otherwise, worldwide forecasts were substituted.

[b]The FAA figures were derived from *FAA Aviation Forecasts: 1996-2007*. The FAA focuses exclusively on U.S. carriers.

[c]Cargo aircraft are excluded.

Modeling Capacity Shortfalls

- Next step is to integrate the results from the capacityand delay models with the economic forecasting models
- By linking cost increases driven by capacity constraints, we can calculate lost revenues and aircraft sales
- Provide additional information to make the business case for significant investments in ATM