Air Transportation
The Next 100 Years
Challenges and Opportunities

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A DAY IN THE LIFE OF AIR TRAFFIC OVER THE CONTINENTAL U. S.

ANIMATION CREATED USING FUTURE ATM CONCEPTS EVALUATION TOOL (FACET)

FOR AVIATION SYSTEMS DIVISION (AF)
NASA AMES RESEARCH CENTER
Overview

- Trends
- Challenges
- Possibilities
Fundamental Need for Travel
Global Travel Time Budget

Source: Schafer and Victor (2000)
Fundamental Need for Travel
Global Total Mobility

Source: Schafer and Victor (2000)
Passenger Traffic by Region

Scheduled Revenue Passenger-Kilometers by Region

Source: ICAO
Historical Demand Trends with Economy
US GDP vs. RPMs: 1954-2001

Source: US BEA and BTS data; Recession data from National Bureau of Economic Research

Original plot by Charlie Keegan, FAA
Conceptual Model

Economy

Direct / Indirect / Induced employment effects

Economic Enabling Effect
(Access to people / markets / ideas / capital)

Travel/Freight Need

Financial Equity/Debt Markets

Demand

Supply

Pricing & Schedule

Airlines

Air Transportation System

Vehicle Capability

NAS Capability

Airline Revenue/Profitability
Air Freight by Region

Freight Tonne-Kilometers by Region

Source: ICAO
World Population Distribution and Air Transportation Activity

Air Transport Source: ICAO, R. Schild/Airbus

North America
38% Pax
27% Cargo
~40 Airlines
~4100 Airports

Europe
27% Pax
29% Cargo
~80 Airlines
~2400 Airports

Latin America/Caribbean
5% Pax
4% Cargo
~40 Airlines
~580 Airports

Africa
2% Pax
2% Cargo
~20 Airlines
~300 Airports

Middle East
3% Pax
4% Cargo
~12 Airlines
~230 Airports

Asia/Pacific
25% Pax
34% Cargo
~60 Airlines
~1800 Airports
Hub and Spoke vs Direct Networks

Completely Connected Network = 2(N-1) Flights
(eg., 50 Airports, 98 Flights)
Fully Connected Network

Completely Connected Network = N(N-1)
(eg., 50 Airports, 2450 Flights)
Demand Drives Frequency Decreasing Aircraft Size
Ten Major US Carriers - Excludes Regional Jets

Source: DOT Form 41 Data
Emergence of Regional Jets

ERJ 145 (50 seats)  CRJ 200 (50 seats)
U.S. Regional Jet Growth

Source: FAA registration data from 1995 until the present
Regional Jet Deployments

DFW Departures

January 1998

Turboprop and Regional Jet Catchment Basin (500 nm)
Narrow Body Jet Catchment Basin (2400 nm)

January 2003

Turboprop Catchment Basin (500 nm)
Regional Jet Catchment Basin (1700 nm)
Narrow Body Jet Catchment Basin (2400 nm)
Proposed - Small Turbofan Passenger Aircraft

Eclipse Jet

Cessna Mustang

Proposed New Aircraft will Extend the Size Spectrum of the Air Transportation Fleet
Proposed New Aircraft will Extend the Size Spectrum of the Air Transportation Fleet
New Operational Class - Unmanned Air Vehicles
Safety Trends

Hull Loss and/or Fatal accidents - Worldwide Commercial Jet Fleet - 1959 through 2001

Source: Boeing 2001 Statistical Abstract
Impact of September 11
US Domestic RPMs

Source: ATA Monthly Passenger Traffic Report
Estimated 484 Aircraft Parked/Retired Worldwide
Effective Modernization of the Fleet

(Source: Avsoft)  

Source: Katherine Andrus, Air Transport Association
US Airline Load Factors 2000-2003

Source: ATA data

Average Load Factor

January 2000 2001 2002 2003
April 2000 2001 2002 2003
July 2000 2001 2002 2003
October 2000 2001 2002 2003
Annual Change in Average Domestic Fare

Source: ATA Monthly Airfare Report; 1000mi domestic trip (all classes); excludes WN -25 -20 -15 -10 -5 0 5 10 % Change vs Prior Year 2000 2001 2002
Airline Profitability Impact

-$/ASM$

<table>
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<tr>
<th>CASM</th>
<th>RASM</th>
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9/11-9/13

Security costs

Quick Recovery

Slow Recovery

Insolvency

Time
All Major Carriers On “Slow Recovery” Trajectory Except Southwest

Quarterly Profit (Loss) in millions

00-1Q  00-2Q  00-3Q  00-4Q  01-1Q  01-2Q  01-3Q  01-4Q  02-1Q  02-2Q

AA  UA  DL  WN

9/11 Attacks

Source: Airline reports

$(1,000)  $(800)  $(600)  $(400)  $(200)  $200  $400  $600
Market Cap: US Majors, 3/18/03
With Jet Blue

- Southwest: 69.9%
- Jet Blue: 11.2%
- American: 1.7%
- Delta: 6.9%
- Northwest: 4.3%
- Continental: 2.2%
- Alaska: 2.9%
- United: 0.4%
- US Airways: 0.0%
- ATA: 0.3%
- America West: 0.4%

Total Market: $15.7 billion

Source: Yahoo! Finance. Includes ATA
Current Market Cap vs. RPM Share
US Majors and ATA

Network vs Cost Efficiency Questions

Source: Yahoo! Finance and airline traffic reports
Southwest SWA Flights
(8/7/02)
Alaska Flights (8/7/02)
American AAL Flights (8/7/02)

DFW 18%
ORD 12%
MIA 6%
Cyclic Industry with Exponential Growth In Volatility Since Deregulation

Source: ATA

NB: 2001 data includes Air Trans Stabilization Act receipts
US Airlines Net Profit Model
Best Fit of Undamped Oscillation
Cycle Period = 11.3 yr  eFolding Time = 6.3 yr

Predicted Losses
2003  $15.6 B
2004  $15.0 B
2005  $8.4 B

- (ATA) Estimate
September 11 Does not Significantly Change Trend

Cycle Period = 12.1 yr      eFolding Time = 7.6 yr

Analysis using only data before 2001

Predicted Losses
2003  $11.3 B
2004  $13.1 B
2005  $11.2 B

Net Profit (Current US$B)

(ATA) Estimate
Growth Limits
Constraints vs Damping

Upside: Capacity, Market

Downside: Financial
Capacity Issues
US Flight Delays

OPSNET National Delays

Month

Total Delays

2002
2001
2000
1999
1998
1997
1996
1995
Capacity Limit Factors

- **Airport Capacity**
  - Runways
  - Gates
  - Landside Limits (including Security)
  - Weather

- **Airspace Capacity**
  - Airspace Design
  - Controller Workload
  - Balkanization

- **Demand**
  - Peak Demand
  - Hub & Spoke Networks

- **Environmental Limits**
  - Noise (relates to Airport)
  - Emissions (local, Ozone, NOX, CO2)
Airport System Capacity Limit Factors

- Runways
- Weather
  - Capacity Variability
  - Convective Weather
- Landside Limits
  - Gates
  - Terminals & Security
  - Road Access
- Downstream Constraints
- Controller Workload
- Environmental
  - Community Noise
  - Emissions
- Safety
Key Terminal System Flows
(adaptive system - impedance matching)

- Airside
  - Add'l Pax Screen
  - Ckd Bag Screen
  - Gate Boarding
  - Security Check
  - Security Point

- Landside
  - Check-In
  - Bag Claim
  - Drop-off Parking
  - Ground Transport
  - Pick-up Parking
CTX 9000 Explosive Detector

500 Bags/hr
Example EDS Before Ticketing Check In

Source: Transsolutions Website
Other Threats
Portable SAMs

SAM-7 Fired at Arkia Airlines B757-300 Mombassa Kenya, Nov 2002
Electronic Processing

- **Airline Tickets #1 Web Product by Value**
  - Browser 1st page effect on marketing
- **Increase in e-Tickets**
  - Interlining of e-Tickets
- **Kiosk check-in**
- **CAPPS II**
Distribution

- Reduction in commissions to travel agents
- Shift to e-tickets (additional charges for paper tickets)
- Increased restrictions on low fares (USAir charges)

Environmental Issues

Noise

- Stage 4 (Equipment)
- Airports (Capacity)

Emissions

Intergovernmental Panel on Climate Change
Replacement Vehicles
Possibilities

- Technologies
- New Operating Paradigms
- New Airports
- New Vehicles
- New Markets
Nano-Technology Example
“MICRO” Gas Turbines

“MACRO”

10,000 parts
Inlet dia = 2 meters
Airflow = 500 kg/sec
Weight = 400 tons
Power output = 150 MW

“MICRO”

2 parts
Inlet dia = 2 mm
Airflow = 0.25 g/sec
Weight = 1 gram
Power output = 10-50 watts

Source: Prof Alan Epstein MIT
MIT-ARO MICRO TURBINE
Example ATC Operating Paradigm
Minimal Noise Procedures

Source: Prof JP Clarke MIT
3° Decelerating Approach (JFK 13L)
Continuous Descent Approach
Louisville Flight Test

5 dBA Reduction Observed
Example ATC Operating Paradigm

UAV Operation

Current Air Traffic Environment

Satellite Relay

Unmanned Aerial Vehicle

Satellite Uplink

(Direct RF link limited to LOS)

Ground Station

RF Transmitter

Air Traffic Control

Manned Commercial Traffic

UAV Operation

Ground Station

Air Traffic Control
Example ATC Operating Paradigm
Formation Approaches
Lateral vs Longitudinal Wake Vortex Separation

- Limited Reduction Possible in Longitudinal Separation due to Vortex Dynamics
  - 20-30% Throughput Improvement
- Lateral Position of Wake well known close to aircraft
- Close Dependant Parallel Approaches or Formation Approaches enabled by accurate guidance technologies
  - 100 - 200% Throughput Improvement
Example New Vehicle
Functionally Silent Commercial Aircraft

Noise signature conventional Aircraft:
- Sideline EPNL: 96.0 dB
- Cutback EPNL: 90.2 dB
- Approach EPNL: 98.5 dB

Silent Aircraft concepts are targeted to:
- Reduce airframe and propulsion noise by 20 to 30 dB
- Improve quality of life near airports
- Reduce the operating and societal cost of noise
- Enable growth of commercial air transportation

What do we mean by “silent”?
- “Silent” means sufficiently quiet that aircraft noise is less than background noise in a well populated area

Heretofore unasked technical question - “what would an aircraft look like that had ...”
- Noise as a prime design variable?
- A design criterion which is a revolutionary step in noise reduction compared to present configurations?

D. Pilczer, A. Manneville, Prof. Z. S. Spakovszky, MIT-GTL
Example New Vehicle
Quiet Super-Sonic Business Jet

- **Market Study**
  - Range
    - Trans-Atlantic (required), Trans-Pacific (desirable)
    - Supersonic over land highly desirable
  - **Trans-Atlantic** 8 - 15 passenger scheduled service viable
  - **15 Year Market**
    - 100 (Pessimistic) - 470+ (Optimistic)
Aerodynamics - Sonic Boom

- Boom shaping shows great promise
  - Mitigate risk early with demonstrator
    - Boom shaping codes TRL 3-4 now*
    - Bring up to 6-7 with demonstrator
    - Define “acceptable” levels for boom
    - Get FAA participation in tests

* Peter Coen, MIT Presentation

Flight demonstrator reduces technological and regulatory risk
Example New Airports
Mega-Float Concept

Tokyo Bay Experiment

Source: www.mlit.go.jp/english/maritime/mega_float.html
Example New Markets
Air Transportation as Enabling Factor in Developing Regions

Infrastructure - Satellite Based Information Technologies have the potential to allow regions with immature air transportation infrastructure to rapidly reach parity with mature systems
Air Transportation as Enabling Factor in Developing Regions

Air Transportation System

- The Air Transportation Industry has an obligation to find economic models which support investment and economic development in these regions.