Air Transportation is a Complex Adaptive System not an Aircraft Design:
Innovation at the Interface of Disciplines

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Problem

- > 11% of US Disposable Personal Income goes to Transportation
- Highways and Airways are Approaching Gridlock and Hub lock
- Traditional Engineering Approaches are Failing to Find Solutions
- New and Innovative Systems Approach is required to overcome Traditional Stovepipe solution shortfalls and Political/Economic Barriers
The Aviation Capacity and Safety Challenge

Air Traffic Could Triple in Next 20 Years

“The current air traffic management system is near its capacity limits with extensive system delays and inefficiencies resulting in annual losses to users estimated at over $3.5B.”
National Airspace System
Hub and Spoke Network

Completely Connected Network = 2(N-1) Flights
(eg., 50 Airports, 98 Flights)
Ref: J. Hansman, MIT
Hub Airports Becoming Saturated

ASYMPTOTIC BEHAVIOR OF AIRPORTS at 4 N.M. Arrival Separation (32 Arrivals/Rw/Hr)

% AIRPORT UTILIZATION

YEAR


San Francisco
John Wayne
Las Vegas
Minneapolis
Newark
LaGuardia

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Air Transportation System at 58% Max Capacity

HUB & SPOKE OPS GROWTH at 57 US MAJOR AIRPORTS

- A/C OPS/YR
- CAP LIM @ 7 Km
- 50% MAX CAP
- 5 Km sep

YEAR

OPERATIONS / YR X 10 E 6


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ATS Delays will Grow Exponentially

![Graph showing predicted delay vs. airport capacity fraction](image)
Inter City Transportation: Time for a Paradigm Shift?

![Graph showing market growth and transportation shifts over time. Key events include:
- 1899: Model T
- 1914: Assembly Line
- 1927: DC-3
- 1940: First VORs
- 1955-1960: Jet Transports
- 1955-2010: Jetliners Displace Props
- 2020-2030: Small Aircraft Transportation System?]}
Vision of the Future for Inter-Modal Transportation

Small Aircraft Transportation System
Fully Connected Network

Completely Connected Network = N(N-1)
(eg., 50 Airports, 2450 Flights)
Ref: J. Hansman, MIT
National Air Transportation Network
ATM System Functional Structure (Boeing Model)
Future Air Traffic Broadband Network Requirements
Next-Generation Data link Communications
System Integration

Technology Challenges -- 2022

- Satellite-based Comm/Nav/Surveillance
  - Infrastructure Investments
    - Second Generation
    - SATS Infrastructure and Aircraft Technologies
    - Create Latent Market

- Single-Crew Flight Deck Systems & Operations
  - Datalink-managed applications software updates
  - Display-less cockpits (Out-the-window fused data)
  - Spread spectrum data radios for Gbps bandwidth

- Pilot Training
  - Cyber-tutors
  - 75% savings in time and cost

- Airframe Systems
  - <$15 per lb. composites, assembled
  - Robotics for manufacturing
  - Automotive synergies

- Propulsion Systems
  - Non Hydro-Carb. propul.
  - <$10,000 engines
  - Quiet propulsion

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Auto Flight Issues

- Large Number of Aircraft will require High degree of GA Flight Deck Automation to Increase Safety
- Control and Communication aspects of Distributed Multi Aircraft environments, evaluation of control laws as a function of Airspace Dynamic Density
- Cooperating Auto Pilots and Collision Avoidance Systems will stress Wireless Communications Bandwidth
  - Loads and Protocols need to be evaluated
- Human - Computer Interaction requires a Cognitive Workload Experimental Evaluation
• BACKUP MATERIAL
Telcom System Issues

Utilization
- Civil Transport
- General Aviation
- Military

Service Provider
- FAA
- Other Government
- Public / Private Commercial

Quality-of-Service
- Timeliness/Latency
- Priority
- Availability
- Redundancy
- Robustness

Phase-of-Flight
- Planning
- Surface Movement
- Terminal Operations
- En Route / Oceanic

Avionics Issues
- Equipage / Avionics Cost
- Applicability Across Platforms
- Mandatory/Primary/Optional
- Architecture - OSA / Proprietary
- Level of Integration

Delivery
- Voice/Data
- Simplex/Duplex
- Broadcast
- Line-of-sight
- Over-the-Horizon

Link Characteristics
- Spectrum / Frequency
- Bandwidth
- Modulation
- Access Technique

Coverage
- Global
- Regional
- Oceanic
- Line-of-Sight
Perceived Barriers to Paradigm Shift

- There is not enough Airspace
- Aircraft are Too Hard to Fly
- Aircraft are Too Expensive
- Flying is Not Safe
- Airports are Too Noisy
Airspace & Airports

• Free Flight Paradigm should allow more aircraft in the enroute airspace
  – ( > X 20 ? )

• > 5,000 Airports in US within 30 minutes of population – Direct Flight Opportunities

• **However:** SATS Operations will Grow like N(N-1) vs. 2(N-1) for Hub and Spoke
Aircraft Human Factors

• Large commercial aircraft now have:
  – 3 axis auto-pilots & auto-landing modes
  – 3 D GPS
  – Moving Map Displays
  – Terrain and Aircraft Collision Avoidance
• Non-Recurring costs have been Amortized
• Recurring costs for new GA should be small
Air Transportation Activity - ETMS Data

US IFR & FLIGHT FOLLOWING AIR TRAFFIC ACTIVITY

NUMBER OF AIRCRAFT ALOFT

TIME OF DAY (HOUR, EST)

0 5 10 15 20 25 30

TH 4/15/99
FR 4/16/99
SA 4/17/99
SU 4/18/99
MO 4/19/99
EST 5433 PEAK
7:30
23:30
A/P Growth Req’d to Avoid Hub Delay Increase (DPAT model)

No major changes to airline schedules, fleet mix, operations
Traffic growth = 2.3% per year Clear weather conditions

Hold delays to today’s levels

Increase in Airport Arrival/Departure Rates

Average Arrival/Departure Delays (minutes per aircraft)