HCI Aero ’06
Next Generation Air Transportation System
Initiative: Methods for the Analysis of
Future Operational Concepts
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Joint Planning and Development Office
Outline for Today

• How has JPDO (EAD) gone about evaluating the potential impact of the NGATS plan – and the benefits of transformation?
• What are the issues for automation design and implementation that must be addressed in the future?
It’s More Than Just the Movement of People and Goods

- Big Return on Investment
- Contributes over $1.3 Trillion/Year in U.S. Output
- Supports 12+ Million American Jobs
- Travel and Tourism an Integral Part of This
- Exports Reduce Balance of Trade Deficit
All Signs Point to Continued Strong Growth

One Billion+ Passengers in U.S. Skies by 2015
2x to 3x Demand by 2025
New Entrants Such as Very Light Jets
Global Market Opportunities for U.S. Companies
U.S. Travel & Tourism to Grow 4.2% Annually
There Are Problems

- Aging, Inefficient, Unreliable and **Costly** Air Transportation Infrastructure
- Reaching the Limits of Capacity
- Failure to Act Will Cost $40 Billion Annually
- Challenges to American Exports/Balance of Trade
- Unsustainable Security + National Defense Costs
NextGen Tangible Benefits

• Meets Greater Demand/Reduces Delays
• Increases Security
• Is Cheaper to Operate and Maintain
• Makes Best Use of the Taxpayer’s Dollar
• Fuels Economic Growth
• Brings Aviation’s Benefits to Main St. USA
• Bolsters U.S. Global Competitiveness
Transformation Started Yesterday

- Real World Improvements Being Delivered Now
- Transformational Building Blocks
- Network Enabled Operations: The Big Picture
- Revolutionizing Air Navigation and Surveillance
Demand Shortfall: The Case for the Investment
Potential Future Demand on the NAS

**Extreme Business Shift**
- 2% shift to micro jets

**Existing Business Shift**
- Smaller aircraft, more airports

Boeing Forecast: 3X

2004

- Flights: 1.4-3X
- Passengers: 1.8-2.4X
- Shift in passengers per flight (e.g., A380, reverse RJ trend, higher load factor)

Note: Not to scale

Terminal Area Forecast (TAF) Growth Projection

2014 and later Baseline analysis will use OEP & FACT Capacities
NGATS Impact on Future Growth

Year (2.3%/year growth)

Factor of Passenger Growth

- Unconstrained Demand
- NGATS + F&E
- OEP H&S
- No Change

- $40 billion annual economic loss
- $100 billion annual economic loss
Future Fleet Mix and Business Model Assumptions

**Future Scenarios**

**Hub and Spoke:**
Current fleet mix and business model (both hub and spoke and low cost carrier point to point)

**Bizshift:**
Growth beyond OEP airport capacities comes from smaller aircraft (approx 100 passenger) and new flights at under-utilized regional airports near OEP airports

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### A. Pax/Cargo Demand

1) Current (1X)
2) TAF Growth to 2014 & 2025 (1.2X, 1.4X)

1) 2X TAF Based Constrained Growth
2) 3X TAF

### B. Fleet Mix/Aircraft Types

1) Current Scaled
2) More Regional Jets
3) New & Modified Vehicles
   - Microjets
   - UAVs
   - E-STOL/RIA
   - SST
   - Cleaner/ Quieter

### C. Business Model/Schedule

1) Current (mostly Hub & Spoke)
2) More Point to Point + Regional Airports
3) Massive Small Airport Utilization
## Future Scenarios Operations Growth

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Percent Growth by User Class</th>
<th>Overall NAS Growth</th>
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<tbody>
<tr>
<td></td>
<td>Air Carrier</td>
<td>Commuter/Air Taxi</td>
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<tr>
<td>2X Ops TAF</td>
<td>142%</td>
<td>100%</td>
</tr>
<tr>
<td>3X Ops TAF</td>
<td>294%</td>
<td>195%</td>
</tr>
</tbody>
</table>

2004 Baseline seed day has a total of ~55K IFR flights

General Aviation (GA) operations only includes IFR itinerant operations
Future Capacity Shortfall by Airport Type

Baseline Hub-and-spoke Scenario

- **Flights Feasible**
- **Flights Lost**
- **OEP Flights Feasible**
- **OEP Flights Lost**

<table>
<thead>
<tr>
<th>Demand Level (relative to 2004)</th>
<th>Flights Feasible</th>
<th>Flights Lost</th>
<th>OEP Flights Feasible</th>
<th>OEP Flights Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2X</td>
<td>61,846</td>
<td>2,493</td>
<td>24,669</td>
<td>1,656</td>
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<tr>
<td>1.4X</td>
<td>70,553</td>
<td>8,053</td>
<td>28,303</td>
<td>5,551</td>
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<tr>
<td>2X</td>
<td>89,870</td>
<td>21,745</td>
<td>43,959</td>
<td>15,590</td>
</tr>
<tr>
<td>3X</td>
<td>107,821</td>
<td>37,703</td>
<td>59,829</td>
<td>24,669</td>
</tr>
</tbody>
</table>

Demand Level:
- **0X** = 2004 levels
- **1.2X**
- **1.4X**
- **2X**
- **3X**
Bizshift1 Increased Regional Airport Utilization

Number of Flights

Average Delay in Mins

2XBizShift1, Normal Sector Capacity
2XBizShift1, 2X Sector Capacity
17.22
2.92
11.20
38.18
99.42
99.18
Baseline Demand (2002) Current Sector Capacities

Snapshot at ~1pm EDT
2X Future Demand

2X Future Demand Current Sector Capacities

Sector Color Loading Index:
- Yellow: 80 – 125% of sector capacity
- Red: 125 - 200% of sector capacity
- Black: > 200% of sector capacity

2X Future Demand
3X Current Sector Capacities

2X Future Demand
2X Current Sector Capacities
Time-of-day Delay Distribution Comparison

Average Total Delay by Time of Day

- May 17
- 2X May 17 with OEP Capacity
- 2X May 17 with independent Runway
- 2X May 27 with OEP Capacity and 2X Airspace Capacity
- 2X May 17 with independent Runway and 2X Airspace Capacity

44.38 minutes
32.06 minutes
18.13 minutes
7.54 minutes
3.29 minutes
Capacity Analysis Approach: from Unconstrained Demand to Feasible Throughput (1 of 2)

- Estimation of “feasible throughput”
  - Flights are eliminated from the future flight schedule after a specified airport delay tolerance or sector capacity is reached
  - Airport constraints are implemented via delay tolerance; maximum allowed delay for future epochs (15-minute windows) is the greater of
    - the maximum delay at each epoch experienced in summer 2000 for the given airport
    - the average of the delays experienced in summer 2000 at the busiest 31 airports
  - Sector capacities are implemented with the Monitor Alert Parameter (MAP)
    - The maximum number of aircraft simultaneously in a sector within a 15-minute window
Capacity Analysis Approach: Details

- We looked at a 3X demand scenario
  - This means we took a current (2004) demand set and extrapolated the demand to 3X based on TAF growth rates
  - We preserved the current prevailing business model (hub & spoke), fleet mix, schedule time-of-day patterns, flight trajectories, and other parameters
- We've run our simulation models in three configurations
  1. Both airport and sector constraints are active
  2. Sector constraints are active but airport capacity is assumed to be unlimited
  3. Airport constraints are active but sector capacity is assumed to be unlimited
- We estimated the feasible throughput based on the following capacity constraints
  - Airport capacities are set based on 2014 Operational Evolution Plan (OEP) airport capacities
  - Airspace capacities are set based on current FAA sector capacities; i.e., MAP values
- We analyzed the feasible throughput, including
  - Where must capacity constraints be addressed (specific airports and airspace), by what magnitude, etc.
## Summary of Capacity Constraints Analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>3X Baseline Demand</th>
<th>3X Feasible Throughput (Airports Constrained)</th>
<th>3X Feasible Throughput (Airspace Constrained)</th>
<th>3X Feasible Throughput (Airports and Airspace Constrained)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flights in NAS</td>
<td>173,980</td>
<td>114,156</td>
<td>142,782</td>
<td>112,595</td>
</tr>
<tr>
<td>Number of Flights Trimmed</td>
<td>N/A</td>
<td>59,824</td>
<td>31,198</td>
<td>61,385</td>
</tr>
<tr>
<td>% of Flights Trimmed</td>
<td>N/A</td>
<td>34%</td>
<td>18%</td>
<td>35%</td>
</tr>
</tbody>
</table>

• Assuming only FAA airport capacity benchmark report airport capacity improvements and no airspace capacity improvements, the portion of demand that cannot be satisfied ranges from 18% to 35%.
• Note that the unsatisfied demand for the Airport Constrained and the Airport/Airspace Constrained cases are almost identical.
Initial Constraints Analysis
Summary Results

Feasible Throughput (flights)

Unconstrained Demand
Both Constraints
Airport Constraints Only
Sector Constraints Only

% Demand Satisfied

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Demand Satisfied (% of Unconstrained)
Flight trimming reduces loading in high sectors in heavily-trafficked corridors between major airports.
Flight trimming reduces loading in super-high sectors in heavily-trafficked areas of the country.
Overall Conclusions

• Airport constraints are more binding, in both scenarios (2025 and 3X)
  – If you only solve the sector constraints, you really haven’t done much for the NAS-wide performance
    • Just a 1% improvement in feasible throughput, in both scenarios
  – If you only solve the airport constraints, you reap a lot of NAS-wide performance benefit
    • However, in the 3X scenario, you still have significant sector constraints that keep you from satisfying all the unconstrained demand

• To satisfy 3X demand, both types of constraints must be resolved
Modeling Operational Improvement Performance
A New Portfolio of Programs Needs to Be Funded in FY08 to Meet 2015 Needs

**Current Programs**

- ERAM
- TFM-M
- STARS/CARTS
- RNP/RNAV
- Initial ADS-B
- Initial SWIM

**New Portfolio of Programs**

- **ERAM Enhancements**
  - Automated Problem Resolution
  - Integrated Controller Suite
- **TFM-M Enhancements**
  - Time-Based Metering
- **STARS Enhancements**
  - Merging and Spacing Tools
- **RNP/RNAV Expansion**
  - Precise Navigation
- **Data Communications**
  - Automated Complex Clearance Delivery
  - Flight Intent Downlink
- **ADS-B**
  - Aircraft Separation
- **SWIM**
  - Net-Centric Information Sharing

**NGATS**

- **Trajectory-Based Operations**
- **Aircraft Data Communications**
- **Performance-Based Operations and Services**
- **Separation Management**
- **Collaborative TFM**
- **Precision Navigation**
- **Weather Integration**
- **Surveillance Services**
- **Network-Centric Information Sharing**
Next Generation Air Transportation System Initiative:
Methods of Analysis of Future Operational Concepts

How do we go about analyzing the impact of Future Operational Concepts?

Questions we really need to address that have not been looked at yet

Outsourcing:

How much should the “skilled” worker do and how much can be outsourced to automation, another element in the system (when it is not busy) etc.

Some important issues that arise are:

how quickly can one come to full situational awareness if a task is outsourced and must be directly managed due to an emergency?

Who is the best owner of authority given varying levels of complexity?

What “must” the automation or oursourced element be able to do to assure safety?
Next Generation Air Transportation System Initiative: 
Methods of Analysis of Future Operational Concepts 

How do we go about analyzing the impact of Future Operational Concepts?

In the past; we operated in a paradigm of organization – to-organization; whether the entity was the Flight Operations Center talking to an Airport Tower, or a Controller talking to an Individual Aircraft; the operational paradigm was one in which the objectives of the ORGANIZATION took precedence over the objectives of the individual.

In today’s environment it is possible for individual pilots to optimize their own environments; for FOCs to optimize for their fleet and for individual controllers to manage the interfaces among many pilots, flight operations centers, and each other, due to the ubiquitous availability of information.
Modeling Process

End Products:
NGATS Throughput (?
Delay profile for RNAV, super-density ops

End Products:
NGATS Throughput (?
Delay profile for RNAV, super-density ops

Segments 3, 5, 7 demand sets (ideally with flights removed between TOD and the runway)

Runs required to trim demand set

Feasible NGATS throughput

Updated airport capacities for super-density ops

ACES runs with RNAV approach trajectories modeled

Sensis

ACES

LMINET

Metron

Environmental analysis of feasible throughput

ACES

Metron

Environmental analysis of feasible throughput

ACES

Metron

End Products:
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Next Generation Air Transportation System Initiative: Methods of Analysis of Future Operational Concepts

How do we go about analyzing the impact of Future Operational Concepts?

Frontiers for Human Factors Analysis and Engineering – The Vital Role of HF analysis in NGATS System Performance Assessment

What is the ROLE of Human Factors Analysis in the Next Generation System Evaluation process?

Concept Definition
Safety Analysis (aircraft, airspace, individuals)
Organizational Design and Overview
Workload / work force requirements
During transition to NGATS
At End-state
Substitution of Automation for Humans – Development of Software Design requirements and Certification Criteria

How will EAD attack this problem?
Theoretically
Analytically
Experimentally
How do we go about analyzing the impact of Future Operational Concepts? The
Next Generation Air Transportation System Initiative:  
Methods of Analysis of Future Operational Concepts

How do we go about analyzing the impact of Future Operational Concepts?

Understanding the system components
- Airports
- Terminal Area Airspace
- Enroute Airspace

The “Exceptions”
- Weather and weather and more weather

Understanding the impact of the NGATS solutions
Things that Enable Improvement
- ADS-B
- SWIM / NEO
- CDTI

Things that Enhance current performance
- EG CDA’s
- RNP/ RNAV
- Wake Vortex Separation Reductions

Things that Replace current system elements
- Dynamic Airspace Allocation
- Required System Performance
- Secondary Airports / Remote and Virtual Towers
- Aircraft to Aircraft Self-Separation
- Aircraft internal health management

THINGS WE CAN’T Know yet!!!
### Safety-Related Components Example 1 - Safe Separation from Aircraft and Vehicles in the Commercial IFR Environment (Case 6)

<table>
<thead>
<tr>
<th>Gate &amp; Taxi-out</th>
<th>Take Off</th>
<th>Climb</th>
<th>Cruise</th>
<th>Descent</th>
<th>Approach &amp; Land</th>
<th>Taxi-in &amp; Gate</th>
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<tbody>
<tr>
<td><strong>Surveillance</strong></td>
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**ASDE**: Airport Surface Detection Equipment  
**ASR**: Airport Surveillance Radar  
**ARSR**: Air Route Surveillance Radar  
**P**: Primary Radar  
**SSR**: Secondary Surveillance Radar  
**NOTAM**: Notice to Airmen  
**SID/STAR**: Standard Instrument Departure/Standard Terminal Arrival Route  
**TCAS**: Traffic Alert & Collision Avoidance System  
**VOR**: VHR Omirange  
**DME**: Distance Measuring Equipment  
**FAR/AIM**: Federal Aviation Regulations / Airman’s Information Manual  
**FAA 7110**: Air traffic Controller’s Handbook
Top of Descent (TOD)

Flight placed on published RNP route from TOD to runway end. No further controller interaction with flight.

Airport capable of handling high-density operations, capacity given by Boeing Airport Capacity Constraint model.

Portfolio Assumptions
Results: Average delay at OEP airports (unconstrained demand flown)

Effect of RNAV to RW and Super Density Ops (OEP35 Airports)

In Segment 3, OEP 35 had RNP approaches and super density capacities.

In Segment 5, top 100 APs had RNP approaches, OEP35 had same super density capacities as Segment 3.

In Segment 7, all commercial APs had RNP approaches, OEP35 had super density caps higher than Segments 3, 5.

Average Total Delay per Flight (minutes)

- No Change
- NGATS

Portfolio Segment

Seg 3

32.4

Seg 5

54.9

105.6

Seg 7

81.8

165.6
Results:
Average delay at all commercial airports (unconstrained demand flown)

Effect of RNP Routes to RW + Super Density Ops (All Commercial Airports)

- In Segment 3, OEP 35 had RNP approaches and super density capacities.
- In Segment 5, top 100 APs had RNP approaches, OEP35 had same super density capacities as Segment 3.
- In Segment 7, all commercial APs had RNP approaches, OEP35 had super density caps higher than Segments 3, 5.
Next Generation Air Transportation System Initiative: Methods of Analysis of Future Operational Concepts

Next Questions???

• Why are current system designs in place – should they be replicated in the transformed system? Will they perform as intended?

• How do we certify a system with so many possible failure modes that an exhaustive analysis is impossible?

• What should the performance requirement / criteria be that ensures that the new system delivers its best capability without overtaxing the system managers?

• **Which criteria should be applied to:**
  Decide that dynamic airspace reconfiguration is needed / warranted,
  Aircraft are capable of meeting the minimum RTSP performance level for access,
  Determine that an unsafe situation is emerging,
  Describe and certify the training criteria to allow individuals to provide these services?