Self-Separation Research at NASA

Briefing to iFLY Consortium

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Outline

- High-Level Concept
- Air Traffic Operations Lab
  - Safety
  - Performance characterization
  - Traffic complexity prevention / mitigation
- Conclusions

- Announcement of special opportunity
Uncertainty of Future Demand Calls for a Scalable Solution

“\textit{The uncertainties in the form of future demand call for a highly flexible solution to avoid over-building with the wrong infrastructure or under-building for the pace of expansion.}”

JPDO, Next Generation Air Transportation System Integrated Plan, Dec. 2004

Goal for NextGen R&D:

\textbf{Scalability}

\textit{(demand-adaptive capacity)}
4D-ASAS Trajectory Management

Research Premise

**Scalability achieved by applying two significant innovations to ATM:**

**Automation**
- Relieve human workload bottleneck
- Increase 4D trajectory precision
- Change nature of “complexity”
- Enable function distribution

**Distribution**
- Retain human active involvement (air/ground)
- Involve aircraft in achieving ATM objectives
- Build in safety through redundancy
- Scale up and down with demand

### Human Functions (Decision Making)
- Establishing goals and preferences
- Selecting between alternatives
- Applying human judgment

### Service Provider Functions (Strategic TM)
- Allocating limited system resources
- Generating trajectory constraints
- Controlling unequipped aircraft

### Automation Functions (Information processing)
- Monitoring for conditions & events
- Computing alternatives & optimums
- Doing routine & predictable tasks

### Aircraft Operator Functions (Local TM)
- Managing trajectory to constraints
- Adjusting trajectory for safety
- Optimizing where flexibility permits

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4D - Four Dimensional
ASAS - Airborne Separation Assistance System
TM – Trajectory Management
4D-ASAS Trajectory Management
Concept for Performance-Based Operations

- The basic idea
  - Instead of ATSP specifying the actual trajectory, they specify trajectory constraints, driven by ATM objectives
  - Aircraft use performance-based capabilities to meet each type of constraint

- ATSP benefits
  - ATM objectives are met, if constraints are properly specified and met
  - System performance predictability is increased, aircraft-by-aircraft

- User benefits
  - Priority handling for equipping
  - Flexibility to self-optimize trajectories, operations
4D-ASAS Trajectory Management
Concept for Performance-Based Operations

Position constraint
Crossing constraint
Hazard avoidance constraint
Arrival time constraint
Path constraint
Traffic spacing constraint
Origin

Traffic separation constraint

Destination

★ Trajectory is otherwise unconstrained
Clear and efficient air/ground trajectory management roles:

- Coordination and negotiation occurs on the constraints
- Negotiation (if needed) involves changing, relaxing, or exchanging constraints
4D-ASAS Trajectory Management
Enabling ASAS Performance Capabilities

Approach: Expand RNP concept with new performance-based functions

- Precision time of arrival
  (4th D, fixed frame)
- Interval management
  (4th D, relative frame)
- Hazard separation
  (4D, relative frame, slow moving hazards)
- Traffic separation
  (4D, relative frame, fast moving hazards)
4D-ASAS Trajectory Management
Defining Trajectory Constraints Properly

Restricts trajectory only where needed to meet specific objectives:

- Excessively constrained trajectory
  - Excessive constraints lead to over-controlling the trajectory
  - Inflexible to changing conditions and unforeseen events
  - Inefficient use of resources

- Correctly constrained trajectory
  - Constraints directly linked to hazards or ATM objectives
  - More trajectory solutions available when constraints are minimized
  - Flexibility is used by operators for self-optimization

Trajectory is otherwise unconstrained
# Macro Performance Levels

<table>
<thead>
<tr>
<th>Performance category</th>
<th>Communications method</th>
<th>Communication object</th>
<th>Loop closure</th>
<th>ATM “friendliness”</th>
<th>Burden on ground system</th>
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<tbody>
<tr>
<td>4D ASAS A/C</td>
<td>Constraint exchange</td>
<td>The constraints</td>
<td>Dynamic RNP</td>
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<td>Intent broadcast</td>
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<td>4D Managed A/C</td>
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<td>The 4D trajectory</td>
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<td>2D-3D Classic A/C</td>
<td>Voice comm</td>
<td>Flight instructions</td>
<td>Follow the</td>
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<td>instructions</td>
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Meta-level challenge: Accomplishing huge paradigm shifts
- From airspace-based operations to trajectory-based operations
- From equipage-based capabilities to performance-based operations
- From human-only control to automation-dominated trajectory management
- From centralized-only architecture to centralized/distributed hybrid architecture

**Metrics of success**
- Demand-adaptive capacity (“scalability”)
- Quantifiable safety
- Behavioral stability and robustness
- System performance predictability
- User operational flexibility & equity

Micro-level challenge: Traffic complexity control within new paradigm
- Redefining complexity and preventing automation from exceeding limits
- Double challenge: Applying this in a distributed architecture!
Air Traffic Operations Lab (ATOL)
Airspace and Traffic Operations Simulation

Filled a gap for modeling future ATM concepts at medium/high fidelity
Originally designed to assess feasibility of distributed ATM concepts

- Concept level operations research
- Rapid prototyping of flight deck automation capabilities (ASAS)
- Initial flight deck interfaces and procedures development
- Technology / concept performance assessment
- Concept-level safety assessment
- Future CNS requirements evaluation

- Multi-fidelity modeling of airborne systems and CNS infrastructure
- Multiple strings on HLA network
- 96 a/c for batch simulation
- 21 a/c for interactive piloted tests
- Leverages NLR TMX simulation
- Specialization on airborne side
- Connects easily to other simulation facilities (e.g. ground-side)
Air Traffic Operations Lab
ADS-B Simulation (1090 MHz)

• Messages and information elements as defined in industry standard (RTCA/DO-242A)

• ADS-B performance model based on RTCA/DO-260A:
  – Range
  – Probability of reception based on interference from various sources:
    • Mode S and Mode A/C radar replies
    • TCAS messages
    • Other ADS-B and TIS-B messages

• Modular architecture allows incorporation of new performance models or message information elements.

• Can incorporate all ADS-B or mixed ADS-B/TIS-B/radar environment.
ADS-B Visualization Tool Shows Reception Probability
Airborne Automation Technology for SSEP
Autonomous Operations Planner

- Working software prototype: “AOP”
  - ARINC 429 data-bus & 702a FMS integration
- Meets traffic, airspace, user, and flow management constraints
- Conflict management consistent with RTCA standards
  - DO-263, SC186 ACM-WG
- Includes additional functionality
  - Conflict prevention tools
  - Right-of-way scheme
  - Trajectory prediction uncertainty
- Tested in simulations with
  - Flow and airspace constraints
  - Cruise and descent flight
  - Pop-up traffic
  - Aircraft blunders
  - Reduced separation scenarios

CD&R - Conflict Detection and Resolution
Status of Research in Self Separation
Overview

Research Focus Areas (1997-2006)
- Feasibility of distributed control
- Safety of distributed control
- Potential for scalable capacity
- Track-constrained operations (different concept)

Results presented in 2-chart format
- First chart: Accomplishments
- Second chart: Research findings and unresolved issues

Simulation experiments and modeling activities
- NLR batch simulations – evaluation of algorithms
- NLR phase I, II, III HITL sims – evaluation of procedures and scenarios
- Langley 2001 piloted sim – comparison of strategic and tactical trajectory management
- NLR/EU 2002 fast-time simulation
- Langley 2002 piloted sim – safety hazard scenario evaluations
- NASA 2003 demand / capacity modeling
- NASA 2003 controller performance modeling
- Langley 2004 batch sim – initial ‘sidewalk’ scenario research
- NASA 2004 integrated air/ground simulation – mixed operations w/ flow constraints
Status of Research in Self Separation
Feasibility of Distributed Control

Accomplishments

• Developed simulation platform suited for design/testing of distributed ATM operations
• Prototyped high-fidelity airborne automation, procedures, concept details
• Tested large variety of scenarios with pilots and controllers
  – Unconstrained cruise
  – Restricted-airspace cruise
  – Flow-constrained cruise/descents
  – Hazard scenarios
  – Mixed-equipage operations
• Resolved many latent design & feasibility issues from previous “Free Flight” research

Batch and HITL Simulations (NLR)

Piloted Simulations (NASA)

Integrated Air-Ground HITL Simulation (NASA)
Status of Research in Self Separation
Feasibility of Distributed Control

Metrics for assessing feasibility
- Automation functionality achieves objectives in challenging scenarios with real-world system limitations
- Achieved or attainable ATM goals in simulation: traffic separation, conformance to airspace / flow constraints
- Favorable pilot & controller ratings on feasibility
- Problems solved or achievable solution approach identified

Research Findings

- **Airborne-only operations**
  - Feasible to at least 3X current traffic (pilot HITL) and 10X (batch simulations – traffic constraints only)
  - Feasible under simultaneous metering, airspace, and traffic constraints to at least 3X current traffic
  - Reaches a limit in post-descent close to merge points, requiring additional tools designed to support merging

- **Mixed airborne / controller-ground-based operations**
  - Feasible to at least 2X current traffic (max of experiment data)
  - Feasible in cruise and descent-transition airspace with dynamic metering and delay absorption (see chart)

Unresolved Issues
- Upper limit of manageable complexity and whether centralized oversight is required to prevent reaching limit
- Extended climbs, interaction with dynamic weather, and transitioning to terminal merging and spacing
- Optimal approach to air/ground coordination in short-notice mixed-control conflicts (controller safety concerns)
- Integration with fully-automated ground-based operations
**Status of Research in Self Separation**

**Safety of Distributed Control**

### Accomplishments

- Qualitatively compared current system and proposed system concept
- Designed and prototyped safety controls in airborne automation
- Eliminated conflict domino effect
- Collected pilot-HITL sim data on blunders, pop-ups, over-constrained conflicts, reduced separation standard, no ATC backup
- Analyzed feasibility of pilot responsibilities in airborne separation

![Layered Safety Design of Airborne Automation](image)

#### Hazard Scenarios from 2002 Piloted Sim

- Layered Safety Design of Airborne Automation
- AOP’s Layered Approach to Distributed Separation Assurance
- Additional Protective Factors
  - Long look-ahead time horizon
  - On-condition intent-change broadcast
  - Intent-based automated conflict detection
  - Alert-based procedures
  - Rapid-update state surveillance
  - Human/automation redundancy
- Protection layers
- Pre-alert
- Continuous surveillance
- Display filtering
- Conflict prevention
- Flexibility preservation
- Right-of-way rules
- Strategic & tactical CR
- Maneuver restriction alerting
- ACAS
- Maneuver restriction alerting
- L0 alert (traffic point out)
- L1 alert (low level alert)
- L2 alert (conflict alert)
- L3 alert (NMAC alert)

**Safety Design**

- Pre-alert
- Level 1 (L1) alert (traffic point out)
- L2 alert (conflict alert)
- L3 alert (NMAC alert)

**Hazard Scenarios from 2002 Piloted Sim**

- Aircraft A
- Special Use Airspace
- Aircraft B
- Identical crossing assignments

1st generation conflict
2nd generation conflict
Status of Research in Self Separation
Safety of Distributed Control

Research Findings

• Airborne separation has benefits in surveillance, human workload, and automation that provide the potential to be exceptionally safe
• Airborne separation can be implemented without ground-based backup or ‘airborne ATC’ pilot skills
• Coordination requirements
  – Domino behavior can be eliminated (see top chart)
  – Implicit coordination is sufficient and preferred over explicit coordination
  – Right-of-way rules (a.k.a. “priority rules”) reduce unnecessary maneuvering and increase predictability, but not shown to be safety critical (see bottom chart)
  – Staggering the conflict alerts is an effective approach to breaking synchronicity of decision-making (a.k.a. “sidewalk scenario”)
• Reducing lateral separation standards does not appear to increase operational risk in pop-up scenarios

Unresolved Issues

☆ Quantified safety performance of airborne separation
☆ Frequency of “sidewalk scenario” and other conflicts and measured effectiveness of prevention methods
• Detailed airborne system design to achieve quantified safety targets (e.g., number of layers of redundancy)
• Safety impact of crew & environment factors
• Controller performance issues associated with mixed control and airborne separation awareness

2002 Sim Data on Domino Behavior

2002 Sim Data on Priority Rules
Accomplishments
• Analyzed physical airspace capacity for 10X increase in traffic demand
• Analyzed workload from batch & HITL simulations up to 3X demand
• Modeled controller workload for mixed control traffic
• Acquired performance metrics from air/ground HITL simulation
• Analyzed air/ground integration and operational issues
Status of Research in Self Separation
Potential for Scalable Capacity

Research Findings

• Physical airspace capacity per sector is sufficient for at least 10X growth
• Sector capacity scales with self-sep. traffic
  – Result of offloading controller workload
  – 85% equipage yields 330% expected post-OEP capacity in nominal weather (see top chart)
• Distributed ATM supports scalability up to at least 3X traffic demand
  – Controller performance in mixed operations is tied to ground-controlled aircraft population (see bottom chart)
  – Controller workload restricts capacity growth of ground-controlled traffic to approximately 1.1X to 1.3X (NLR/EU result)

Unresolved Issues

☆ Capacity growth limitations due to traffic/airspace complexity
• Controller workload impact as air/ground control ratio exceeds current experimental data (2:1 ratio)
• Performance and issues affecting capacity in situations of high pilot-perceived workload
• Capacity benefit due to distributed control in weather-impacted scenarios (e.g. reduction in weather-related delays)
Status of Research in Self Separation
Track-Constrained Operations

Accomplishments

• Developed an end-state concept description: Dynamic Multi-track Airways (DMA)
• Conceptually analyzed 9 critical concept-design issues
• Modeled and analyzed multi-track alternatives
• Analyzed capacity benefits of a single DMA
• Analyzed expected city-pair demand DMAs
• Prototyped track spacing and passing capabilities
• Analyzed potential as a transitional near-term concept
Status of Research in Self Separation
Track-Constrained Operations

Research Findings

- Airborne separation is feasible within an isolated multi-track airway
  - Operational complexity significantly increased by interaction through intersections, merges, and crossing traffic

- Biggest feasibility challenges are
  - Traffic flow management
  - Multi-track airway network design and management
  - Preserving user benefits (see top chart)
  - Dynamic airway adjustment for weather

- Feasibility of human roles
  - Least feasible is the corridor controller
  - Most feasible is the flight crew

- Multi-track airway system absorbs limited demand
  - 25 most likely pooled routes would serve ~10% of total operations (see bottom chart)

Unresolved Issues

- Utility as a transition step to future operations involving airborne separation
- Feasibility of developing flow-management automation
- User benefits and participation incentives

Load Analysis of Nominal/Passing Track Configuration

- Track loading = 30%
  - 33.3 NM average initial spacing
- Track loading = 40%
  - 25 NM average initial spacing
- Track loading = 50%
  - 20 NM average initial spacing
- Track loading = 60%
  - 16.7 NM average initial spacing

User benefits degrade above ~40% loading

Demand Analysis of Pooled City Pairs and NAS-wide Fraction

- Red = Top 10
- Blue = Next 15

300 nmi minimum length
Selected Self-Separation Activities

• Quantifying safety in high traffic density
  – Measure safety metrics in a series of high-fidelity batch simulations of increasing realism

• Assessing performance impact of influencing factors
  – Isolate effects of delays, errors, uncertainties, interference, complexity on safety, efficiency, task frequency

• Investigating techniques to mitigate traffic complexity
  – Develop metrics and algorithms for predicting/preserving trajectory flexibility and minimizing constraints

• Assessing uncertainty handling techniques
  – Size and tune of prediction-uncertainty buffers
Experiment Scenario

1st Fix
Ownship randomly generated at boundary of outer ring.

2nd Fix
On opposite side of boundary of Test Region

3rd Fix
Outside Test Region, 500NM from 1st Fix, RTA

Initialization Region

Test Region Diameter = 160 NM
1 Flight Level Only

Aircraft's Initial Trajectory

Ten minutes of look-ahead time
Safety of Self Separation

Traffic Demand Levels

- Demand level calibration using the NASA ACES tool
  - Determined the traffic count for every high altitude sector in the United States, at each flight level, for the 1 hour period

- Analysis based on ETMS flight data from 19 February 2004
  - JPDO’s good weather, high-traffic day representing “1X” density

- High-altitude sectors selected based on traffic density
  - Median: ZOA31
  - Dense: ZOB46

<table>
<thead>
<tr>
<th>Traffic Count at FL310</th>
<th>Median Sector ZOA31 (Oakland Center)</th>
<th>Dense Sector ZOB46 (Cleveland Center)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Density</td>
<td>16,624 NM$^2$</td>
<td>5,959 NM$^2$</td>
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<tr>
<td>Peak Density</td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Normalized 1X Density per 10,000 NM$^2$</th>
<th>Median Density</th>
<th>Peak Density</th>
<th>Mean Density</th>
<th>Peak Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Count at FL310 (busiest altitude in these sectors)</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Normalized 1X Density per 10,000 NM$^2$</td>
<td>1.8</td>
<td>3</td>
<td>8.45</td>
<td>16.85</td>
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</table>
Safety of Self Separation
Summary of Simulation Runs

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<thead>
<tr>
<th>Test Region 20,106 NM²</th>
<th>Sustained Traffic Density</th>
<th>Normalized Traffic Density Ratio</th>
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<tbody>
<tr>
<td></td>
<td>Normalized to 10,000 NM²</td>
<td>ZOA31 (Median Density)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZOB46 (High Density)</td>
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<tr>
<td>Run Set</td>
<td>Mean</td>
<td>St. Dev.</td>
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<tr>
<td>1</td>
<td>3.45</td>
<td>0.59</td>
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<tr>
<td>2</td>
<td>6.11</td>
<td>0.83</td>
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<tr>
<td>3</td>
<td>8.61</td>
<td>0.97</td>
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<tr>
<td>4</td>
<td>11.64</td>
<td>1.23</td>
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<tr>
<td>5</td>
<td>15.24</td>
<td>1.49</td>
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<td>6</td>
<td>17.18</td>
<td>1.54</td>
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<table>
<thead>
<tr>
<th>Run Set</th>
<th>Sim Hours</th>
<th>Flights</th>
<th>Flight Hours</th>
<th>Conflicts</th>
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<tr>
<td>1</td>
<td>36</td>
<td>881</td>
<td>237</td>
<td>195</td>
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<td>2</td>
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<td>1527</td>
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<td>3</td>
<td>36</td>
<td>2195</td>
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<td>4</td>
<td>36</td>
<td>3000</td>
<td>797</td>
<td>1788</td>
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<td>347</td>
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<td>6</td>
<td>12</td>
<td>1560</td>
<td>399</td>
<td>1256</td>
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<tr>
<td>Totals</td>
<td>168</td>
<td>10,465</td>
<td>2744</td>
<td>5770</td>
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</table>

Range Tested

Run set 6
10x playback speed
Mean Density 17.18 aircraft per 10000 NM²
Mean Density 17.18 aircraft per 10000 NM2
Safety of Self Separation
Predicted Distance at Closest Point of Approach (CPA)

Predicted Distance at CPA

Count

Distance (nm)

0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00 180.00 200.00

- 3.45
- 6.11
- 8.61
- 11.64
- 15.14
- 17.18

0 2 4 6 8 10 12 14 16 18
Safety of Self Separation
Actual CPA as Flown

Actual Distance at CPA as Flown

Three penetrations of 0.014, 0.011, and 0.001 NM.
Safety of Self Separation
Second Generation Conflicts

• Created as a result of solving a previous conflict
  – Sidewalk (same aircraft, both simultaneously resolving)
  – Coincidence (different aircraft, both simultaneously resolving)
  – Postponed or traded (time-to-loss-of-separation purposefully delayed)

• Associated with system stability and efficiency

• Only 11 conflicts were identified as possibly second generation
  – Out of 2744 simulated flight hours and 5770 conflicts
  – Type: coincidence conflicts
  – With initial detection occurring near 10 minutes from predicted loss of separation, all of these cases were safely resolved
### Performance Characterization of SSEP

**Planned Parametric High-Fidelity Batch Studies**

<table>
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<th>Categories</th>
<th>Parameters</th>
<th>Sensitivity</th>
<th>Cumulative Impact</th>
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<tbody>
<tr>
<td>ADS-B Surveillance Performance</td>
<td>Interference Level</td>
<td>Each parameter</td>
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<td></td>
<td>Amount of Intent Broadcast</td>
<td>tested individually</td>
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<td></td>
<td>Transmission Rate</td>
<td>through appropriate</td>
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<tr>
<td>Trajectory Prediction</td>
<td>Truth Wind Strength</td>
<td>range of interest</td>
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<td>Uncertainty Sources</td>
<td>Forecast Wind Error Vector</td>
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<td>Management Constraints</td>
<td>Aircraft ANP</td>
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<td>Maneuvering Constraints</td>
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<td>Climb Performance</td>
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<td>Coordination and</td>
<td>Priority Rules</td>
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<td>Responsiveness</td>
<td>Pilot Response</td>
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<td>IFR/AFR Operations Mix</td>
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<td>Traffic Geometry Variability</td>
<td>Detection Horizon</td>
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<td>2D Route Structure</td>
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<td>3D Flight Phase Mix</td>
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All parameters to be tested at ~1x, 3x, 5x traffic density
Traffic Complexity Prevention / Mitigation
Research Objectives

ATM Objectives
- e.g. Ensure Safety
- e.g. Ensure Stability
- e.g. Ensure Cost-effectiveness

Trajectory Constraints
- e.g. Separation Requirements
- e.g. Required Time of Arrival (RTA)

Trajectory Constraint Minimization
- Prevent Excessively Constraining Trajectory without Jeopardizing ATM Objectives

Trajectory Flexibility Preservation
- Preserve Ability to Accommodate Unforeseen Events

Trajectory Complexity Prevention and Mitigation

Research Objectives

• What is impact of trajectory constraint minimization on trajectory ‘flexibility’ preservation?

• What is impact of trajectory ‘flexibility’ preservation on traffic ‘complexity’ prevention and mitigation?
Traffic Complexity Prevention / Mitigation
Current Centralized Operations

Centralized Complexity (e.g. Controller workload)

Ensure Separation

Mitigate Complexity

Pilot

Control Tower

Traffic Manager
Traffic Complexity Prevention / Mitigation
Future Distributed Operations

- Ensure Separation
- Preserve Flexibility
- Negotiate Constraints
- Mitigate Complexity
- Minimize Constraints

Distributed/Automated Complexity (Represented by TBD)

Ensure Separation
Preserve Flexibility
Negotiate Constraints

Controller

Pilot

Traffic Manager

Centralized Complexity (e.g. Controller workload)
Traffic Complexity Prevention / Mitigation
Flexibility Preservation

- Traffic Congestion Situation
  Flow Management Without Flexibility Preservation

- Flow Management With Flexibility Preservation

**Airborne flexibility function will question:**
Do I have enough flexibility to safely proceed?
Can I modify my trajectory to increase my flexibility?
Do I need to avoid this airspace entirely and replan?

**Hypothesis:**
If all aircraft apply flexibility preservation function, complexity automatically will be reduced

"Two roads diverged in a wood, and I— I took the one less traveled by,
And that has made all the difference" ...Robert Frost
Traffic Complexity Prevention / Mitigation
Constraint Minimization

Solution Space before Constraint Relaxation
- Aircraft A
- Aircraft B
- Aircraft C
- Aircraft D
- Weather system
- Conflict free trajectories meeting RTA tolerance for aircraft A
- Conflict resolution look-ahead horizon
- Ownership aircraft A
- Flexibility planning horizon
- RTA at fix
- ETA at fix
- RTA tolerance
- ETA range for conflict free trajectories meeting RTA
- Conflict

Solution Space after Constraint Relaxation
- Extended RTA tolerance
- Extended ETA range for conflict free trajectories meeting RTA
- More flexible conflict free trajectories meeting RTA tolerance – Reducing aircraft A contribution to complexity
- Aircraft B
- Aircraft C
- Aircraft D
- Ownership aircraft A
Traffic Complexity Prevention / Mitigation
Example: Single RTA

- Single RTA
- Fixed path
- Varying speed
Traffic Complexity Prevention / Mitigation
Example: Multiple RTA and Traffic Conflict

- Multiple RTA
- Conflict constraints

Diagram showing non-feasible region, feasible region, conflict region, and trajectories. The diagram includes symbols for RTA1, RTA2, V_min, V_max, s_1, d_1, d_2, d_3, d_4, and t. The text and diagram illustrate the concept of traffic complexity prevention and mitigation through multiple RTA and traffic conflict constraints.
Conclusions

- Continuous study of self separation since 1998
- Results all point to positive feasibility, safety potential, and benefits
- Research is shifting to higher fidelity investigations
  - Safety quantification
  - Performance characterization “under the influence”
  - Complexity management
  - Trajectory prediction uncertainty handling
- Potential opportunities for NASA and iFLY to leverage each other’s activities
  - Operational concepts; algorithm experience; safety/complexity analyses; performance with failure/degraded modes

(Wait! One more important slide...)
ATC Quarterly Special Issue on ASAS

- “Special Issue” focusing on specifically on ASAS
  - Guest editor: David Wing
  - First ASAS Special Issue since 2005 (Vol 13, #2, Casaux)
- Soliciting a paper from iFLY on self-separation research
  - Can include one or more iFLY activities
  - Focus on technical activities, data, results
- Timing
  - Target for final draft paper: March 2008
  - Near term need: 1 page abstract and commitment

http://www.atca.org/information/quarterly_desc.asp