CR5DT Computational Platform for "Continuous Replanning of Flight Paths"

Capability Overview

NextGen AeroSciences, LLC
Williamsburg, Virginia, USA

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FAA Williams J. Hughes Technical Center
Atlantic City, New Jersey

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Topics

- V&V Objective
- Scientific & Mathematical Framework
- Continuous Replanning Distinctions / benefits
- Demonstrations
- Applications domains
- Summary Remarks

This presentation provides an overview of NextAero's capability for continuous replanning of flight paths in the context of competing constraints and objectives.

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V&V Objective

- How to conduct technical evaluation of Continuous Replanning for Flight Paths
- While managing competing constraints:
  - Safety: Seeking to be always conflict-free
  - Economics: Seeking robust cost functions
- In the presence of uncertainty
- With computational speed adequate for fast-time use in airspace and aircraft management
- Based on a “theory of airspace”

CR5DT technology
supports a long-standing need in airspace modeling and simulation:
How to generically represent flight paths for multi-objective purposes.

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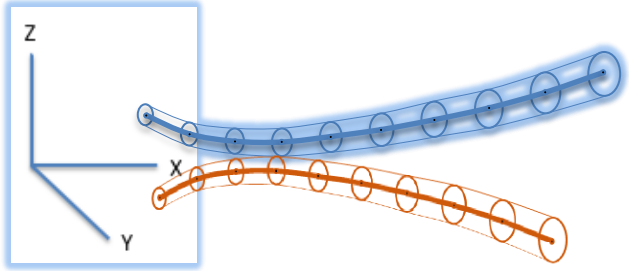
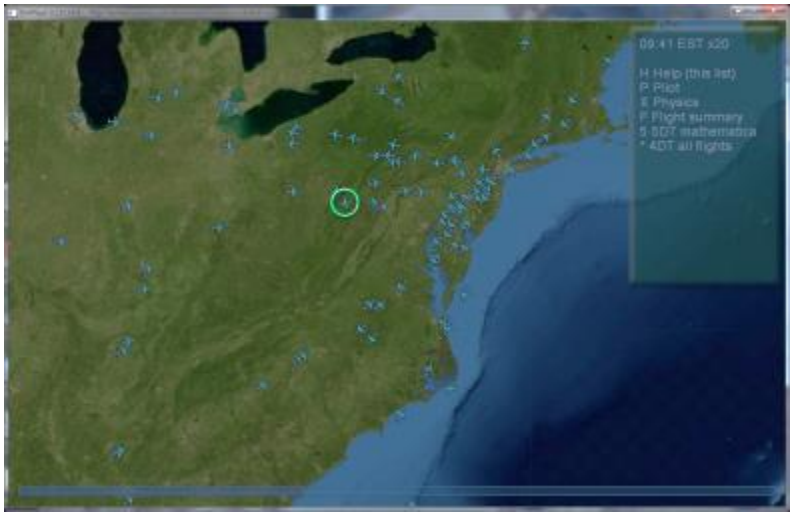
Science & Mathematical Framework



- Minimum of underlying assumptions
- Represent Trajectory as Extended Object
  - Trajectory paths are “strings” (polynomial splines), encoding flight physics
  - Path nodes contain intent and constraints
  - Flight path is constrained at end points
  - Paths repel each other (satisfy separation objectives)
  - Optimization pulls the paths taught (satisfy economic objectives)
  - Fast to compute (physics and math well matched for GPU computation)
- Search the space for “flyable” paths (efficient combinatoric search)
- Select path sets that maintain high optionality (robust solutions)
- Operational constraints:
  - Trajectory separation
  - Minimum fuel
  - Airspace procedures
  - Required Time of Arrival
  - Closed airspace
  - Weather separation
  - Acceleration limits (policies)



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CR5DT Computational Observations

These cases for continuous replanning have been evaluated:

1. Scheduled Time of Arrival with Automated Sequencing
2. Conflict-Free Airspace
3. Blunderer Avoidance

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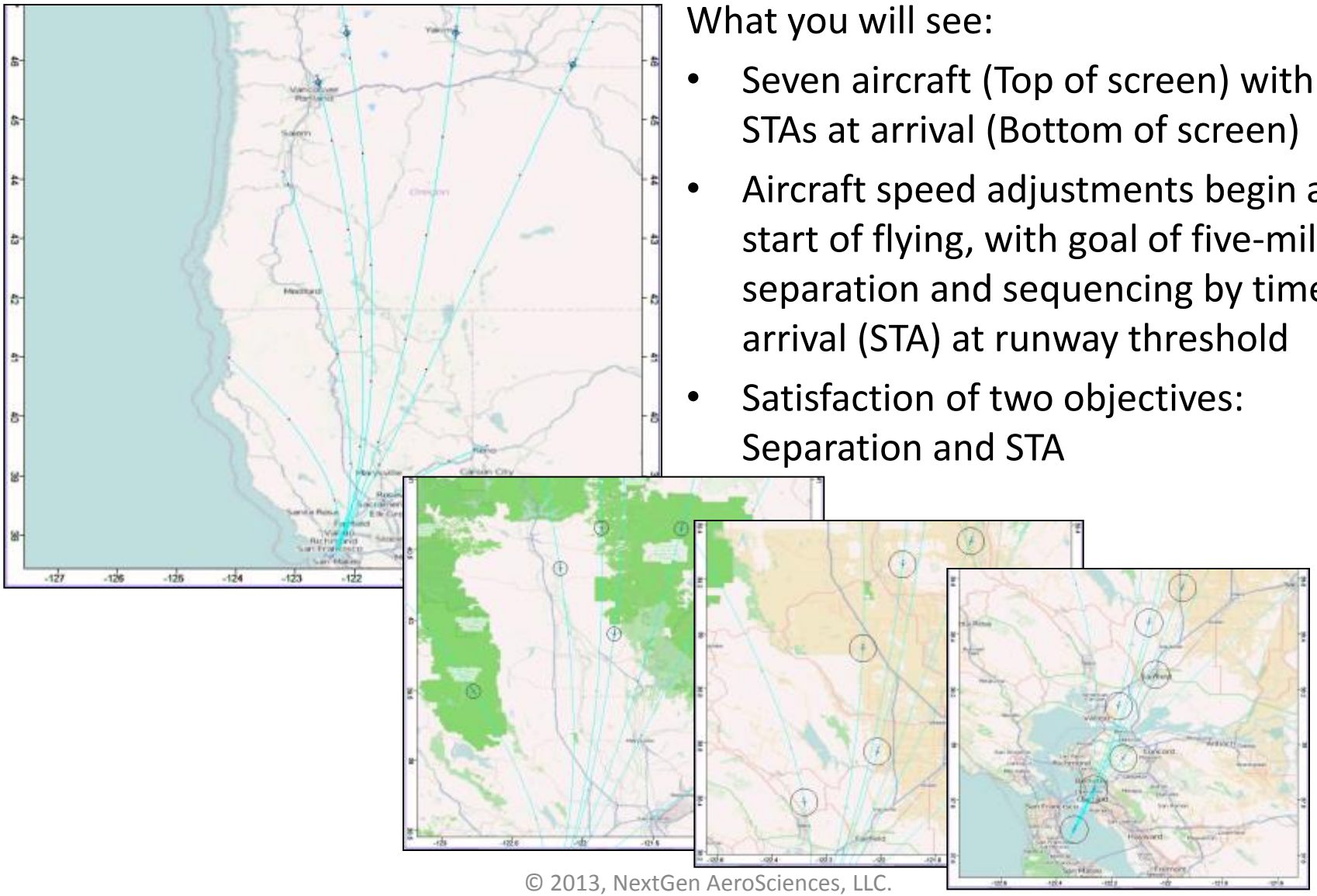
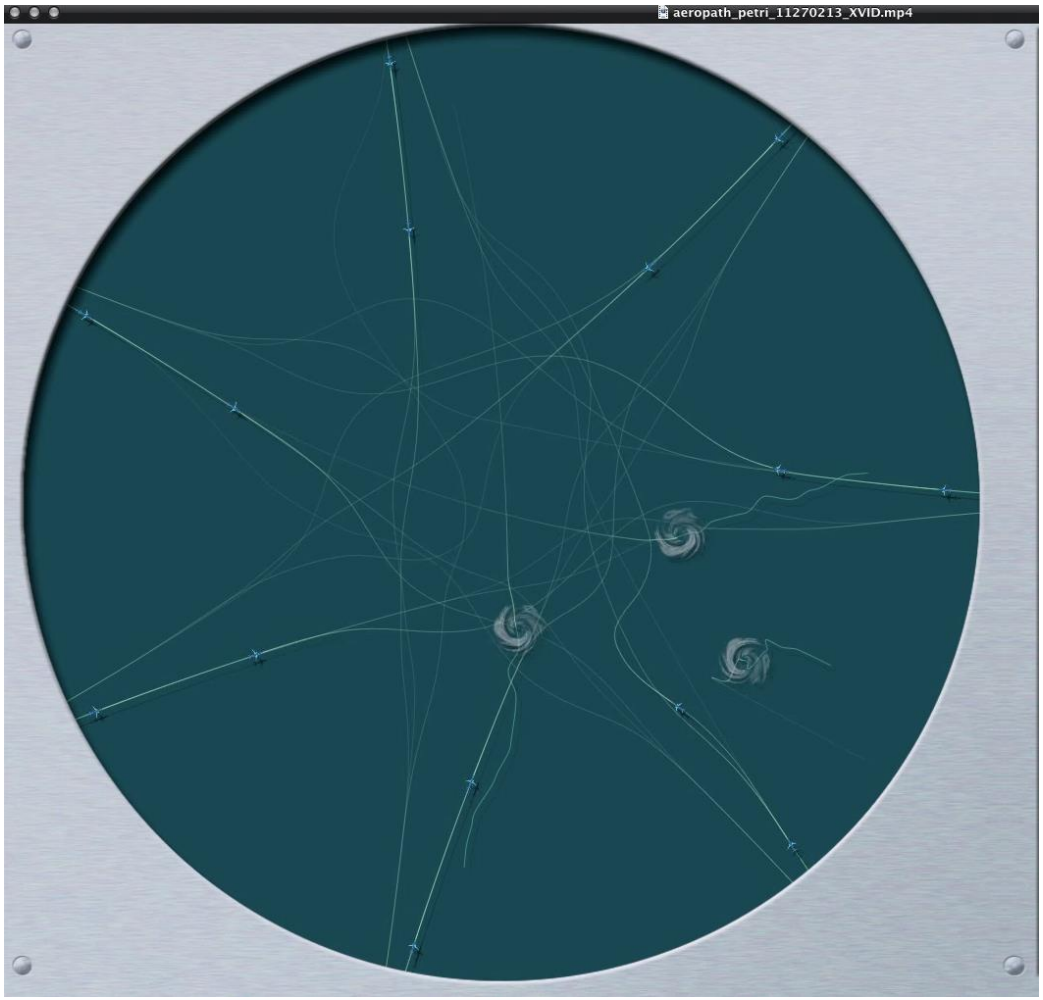
Scheduled Time of Arrival (STA) with Automated Sequencing



What you will see:

- Seven aircraft (Top of screen) with STAs at arrival (Bottom of screen)
- Aircraft speed adjustments begin at start of flying, with goal of five-mile separation and sequencing by time of arrival (STA) at runway threshold
- Satisfaction of two objectives: Separation and STA

24 Aircraft: Resolved Conflict-Free Airspace with Emergent Traffic Flow Pattern



- Storms introduce “noise” to the computation
- Aircraft paths are flexing to avoid conflict and tensioning to meet end-point objectives
- The red streaks illustrate predicted loss of separation
- Example of conflict-free airspace

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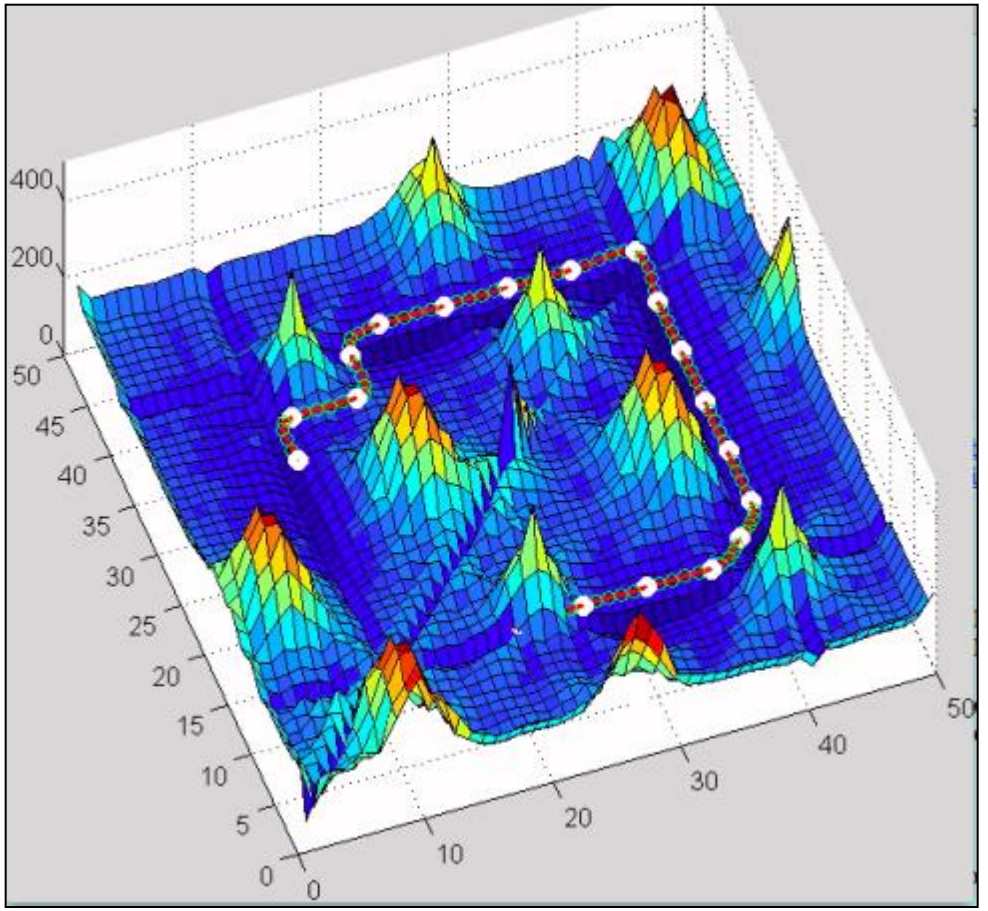
Blunderer Avoidance

- What you will see:
  - 3-D airspace with randomly moving 3D “blunderers”
  - Prescribed flight path “mission” objective
  - As flown “actual” flight satisfying separation and economic objectives



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• CR5DT Distinctions and - FAA Benefits

Emergent trajectories vs. prescribed flightpaths	• Emergent traffic flow phenomena - to produce airspace efficiencies • Fast-time design of traffic flow configurations - to improve airspace throughput • Automation of airspace management - to reduce workloads
Continuous trajectory replanning vs. amended flight plans	• Replacing fixed contracts with continuous replanning - to improve airspace economic and capacity outcomes • Managing airspace "state" in deconflicted form - to improve capacity • Controlling airspace "bulk" properties - to reduce workloads
Longer look-ahead times for trajectories (> 30 or 60 minutes)	• Earlier signatures of congestion - to provide more efficient TMI actions • Earlier decisions on push-back times, speeds, routings - to improve capacity and economics • Earlier arrival sequence planning - to improve passenger connection management

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How To Evaluate Stochastic Outcomes

- We are substituting a randomly selected flight path in the ASDI data for a “day in the life” of the NAS
- First steps: No wind, no controller interactions, no exclusionary airspace
- Observe generated flight path: Does it make sense (laws of physics)?
- Next steps: Add constraints (wind, etc.)
- Challenge: Observe thousands of flight paths.

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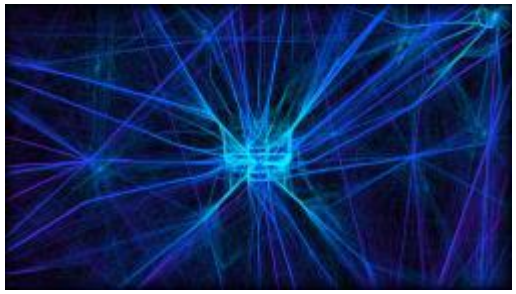
CR5DT Applications – Domain Concepts



- ***Ownship*** Flight Path Optimization with Continuous Replanning
  e.g., FIM-A
- Continuous ***Fleet*** Economic Optimization (AOC- or ANSP-centric)
- ***En Route*** Traffic Management
  - Multi-sector planning automation concepts
  - Conflict-free sets of flight paths (long look-ahead times)
- Interacting ***Metroplex*** Terminal Traffic Management
  - Arrival /departure "early warning"
  - Pre-phase transition flow control
    (speeds, flight paths, sequencing, merging, spacing)
- ***Surface / Arrival-Departure*** Flow Integration (Gate-to-Gate)
- FAA Command Center Playbook Generation (disruption recovery)
  - Continuous replanning versus pages from the playbook

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Summary Remarks

- The CR5DT Platform, based on a “theory of airspace,” enables testing of broad hypotheses of value to the ANSPs and users of airspace
- The CR5DT Platform mathematical formulation provides a generalized representation of flight paths for rapid computation of safety and economics
- Applications appear useful for multiple domains: individual aircraft, fleet-level, and airspace-level modeling and simulation and solutions (systems of systems)

Thank You

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