Probabilistic Analysis of Wake Encounters for NextGen

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Participants

- Berkeley
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- George Mason
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- MIT
  - John Hansman, Alexander Donaldson
- Virginia Tech
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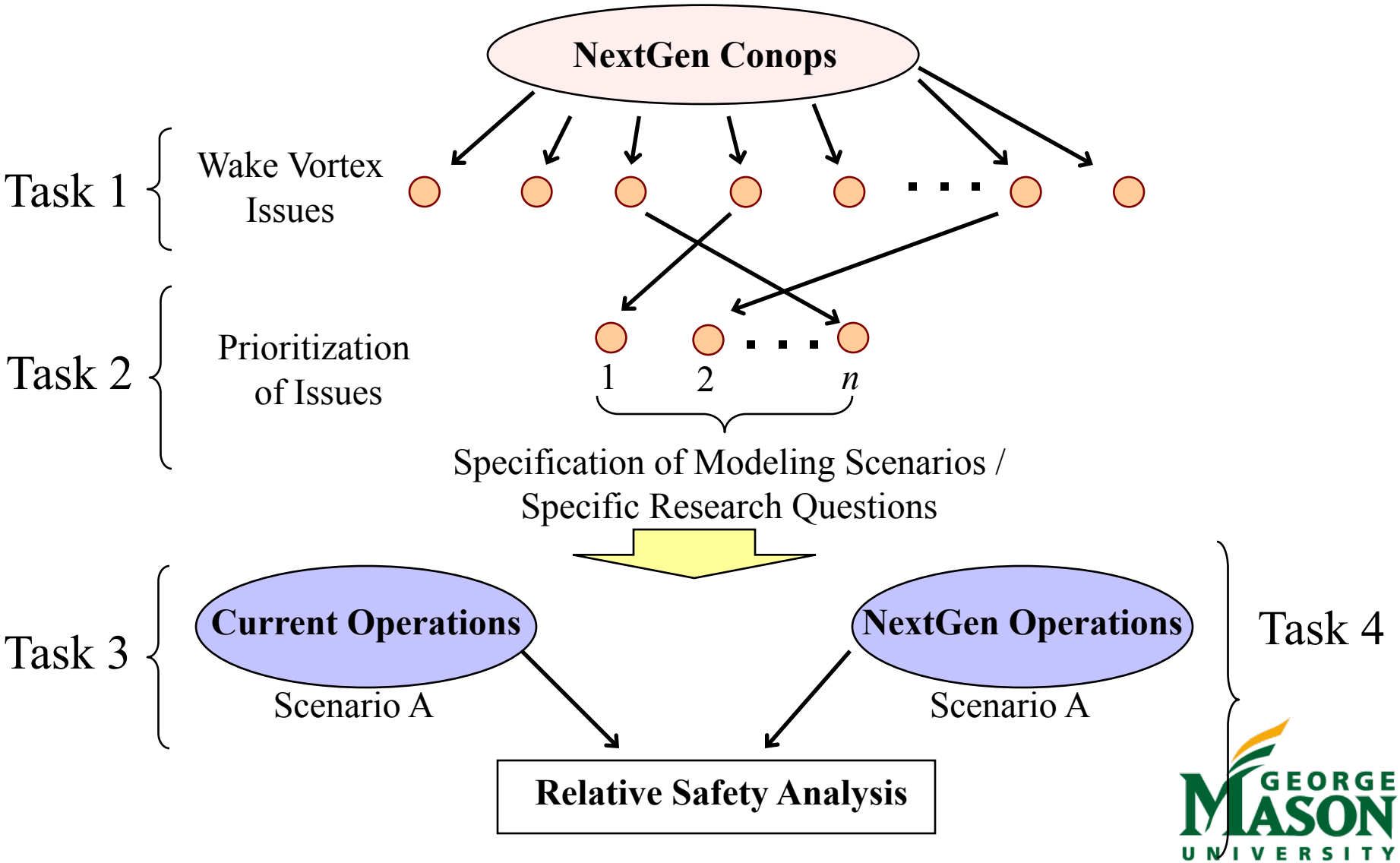
Key Question

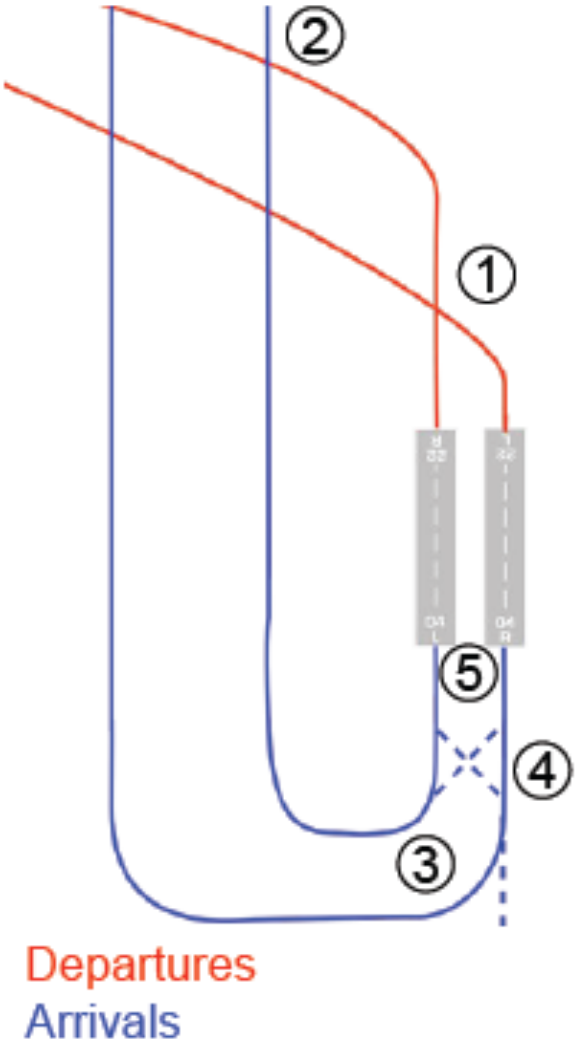
Where do we need to worry about wake vortices in NextGen concepts?

Project Summary



Potential Problem Areas

1. Between departures on CSPR
2. Between departure and arrival flows
3. Merge of arrival flows onto CSPR
4. Crossover maneuvers
5. On closely-spaced approaches



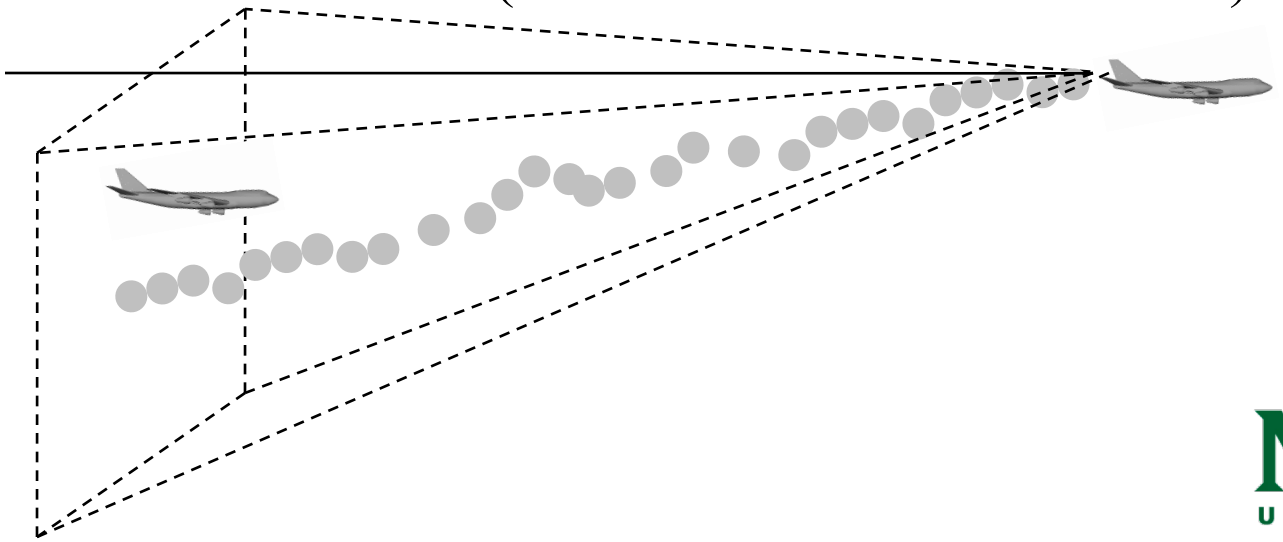
Donaldson, Hansman. 2009. MIT Update. NY/NJ Operations

Flight Tracks

First-Order Approach

Objective: Identify if any NextGen problem areas exist today.

- Define “wake zone” as region that is very likely to contain the wake.
- Current shape of wake zone is notional. Assumed rigid and fixed dimensions
- Count instances where one airplane passes through the wake cone of another (defined here as a *wake alert*)



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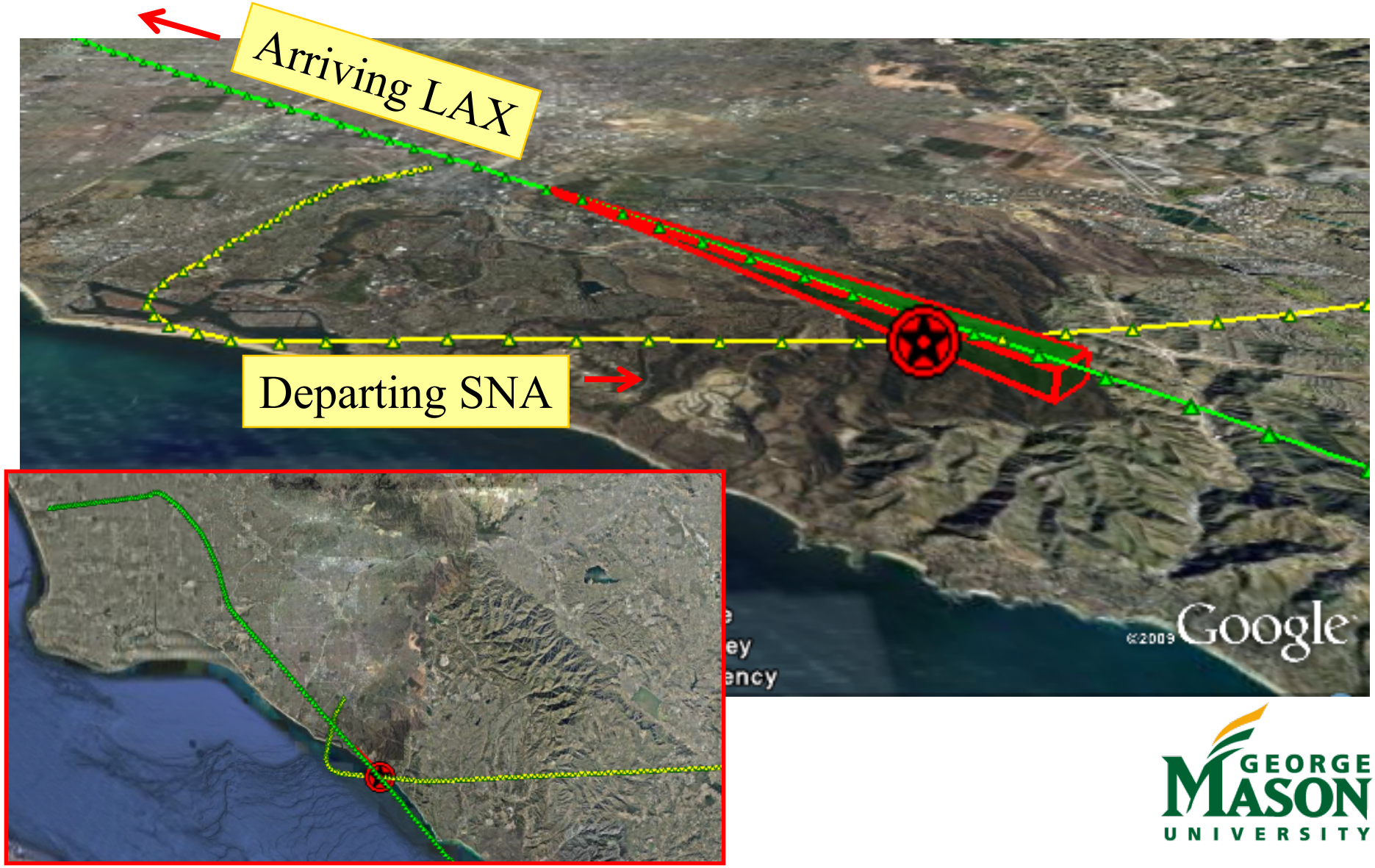
Sample Wake Alert



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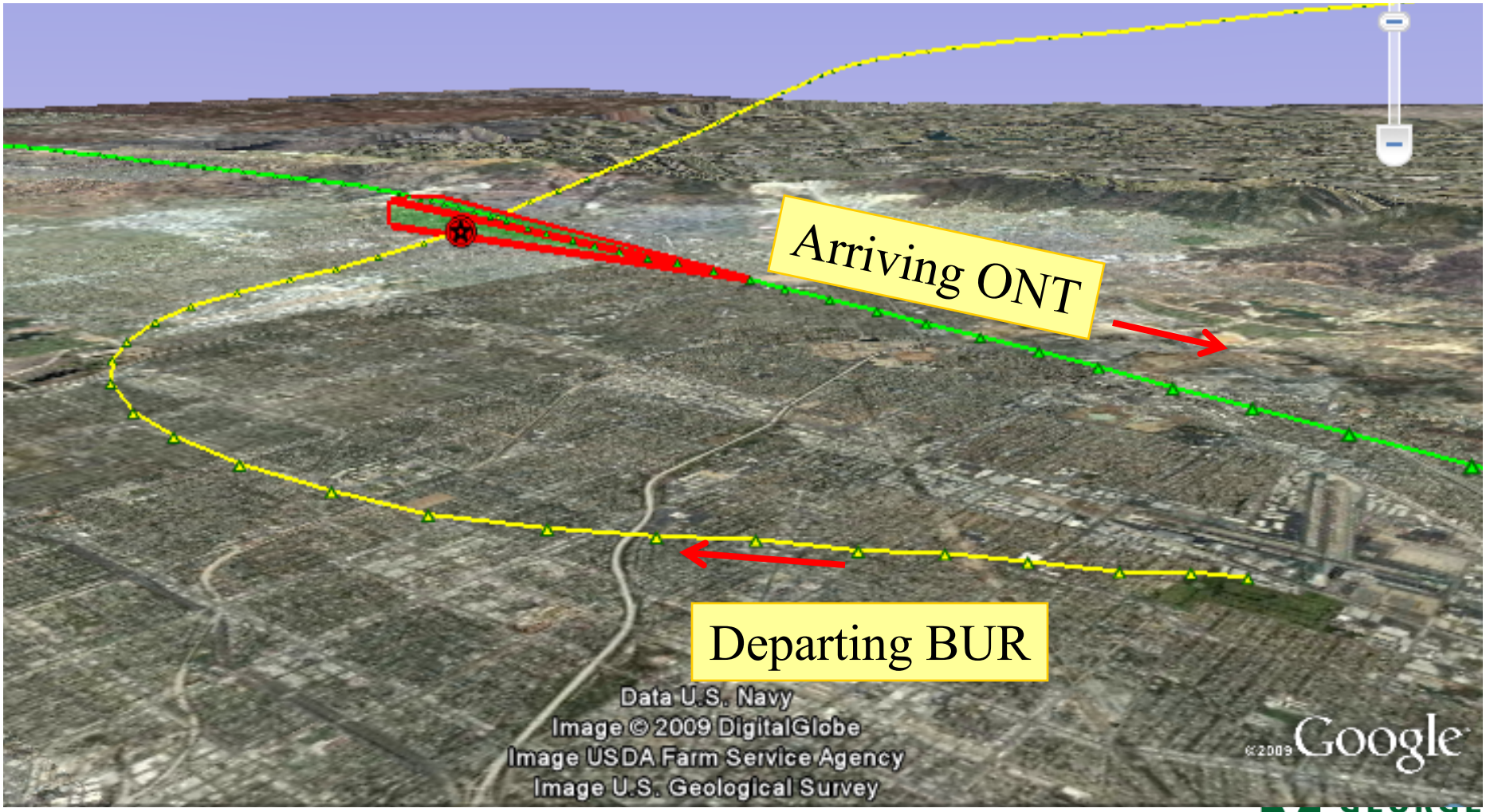
Sample Wake Alert



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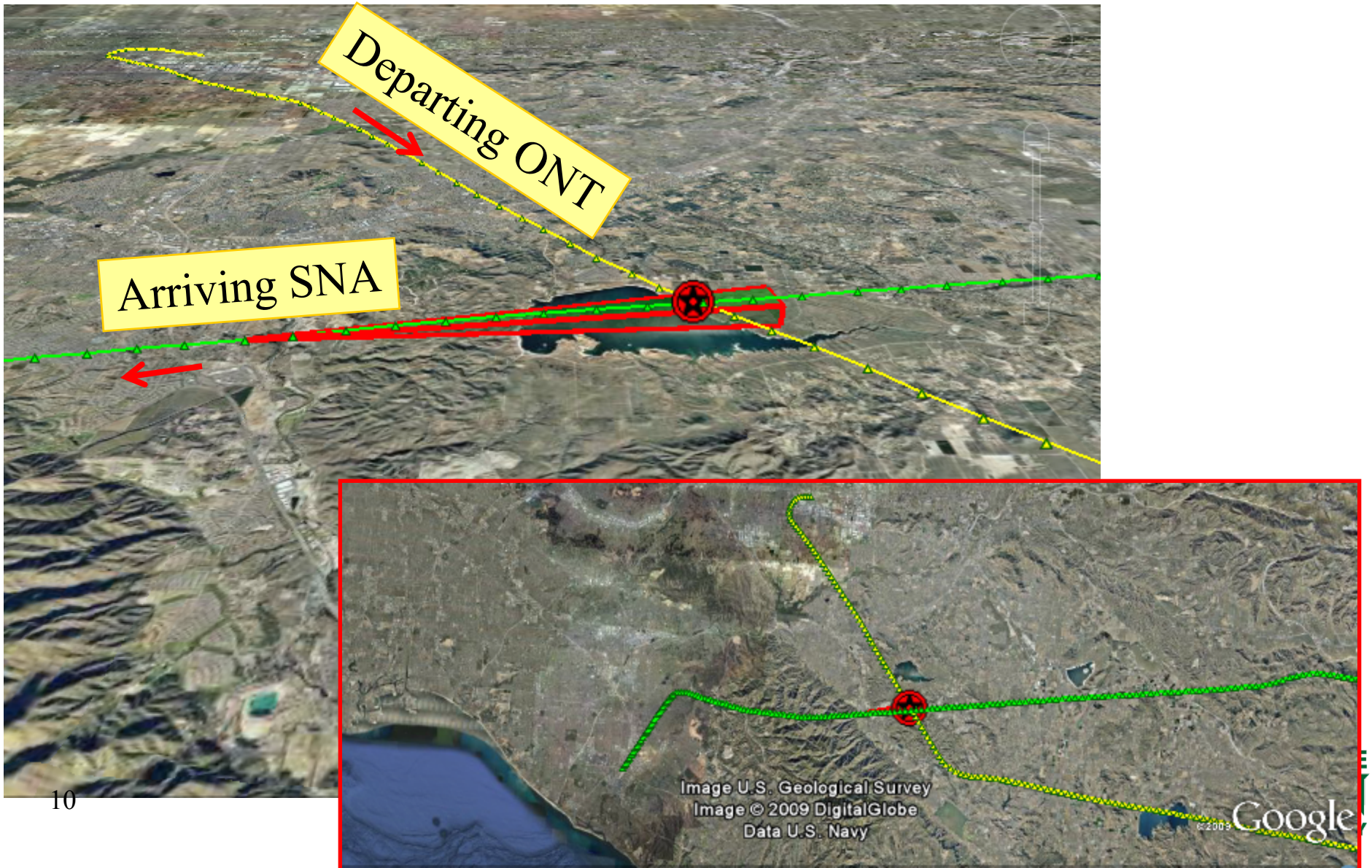
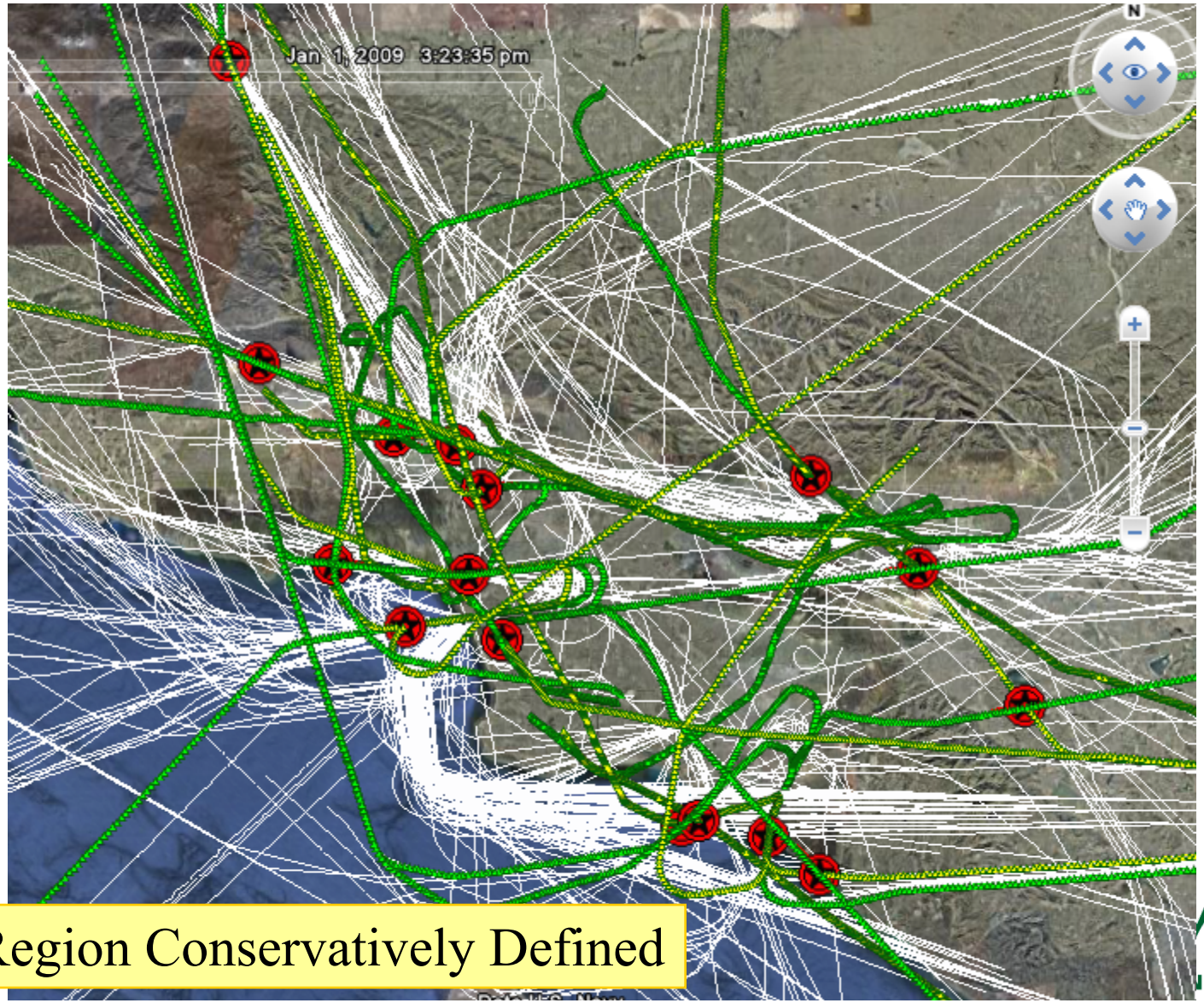
Sample Wake Alert



All Wake-Alert Tracks, 1 Day



Wake Region Conservatively Defined

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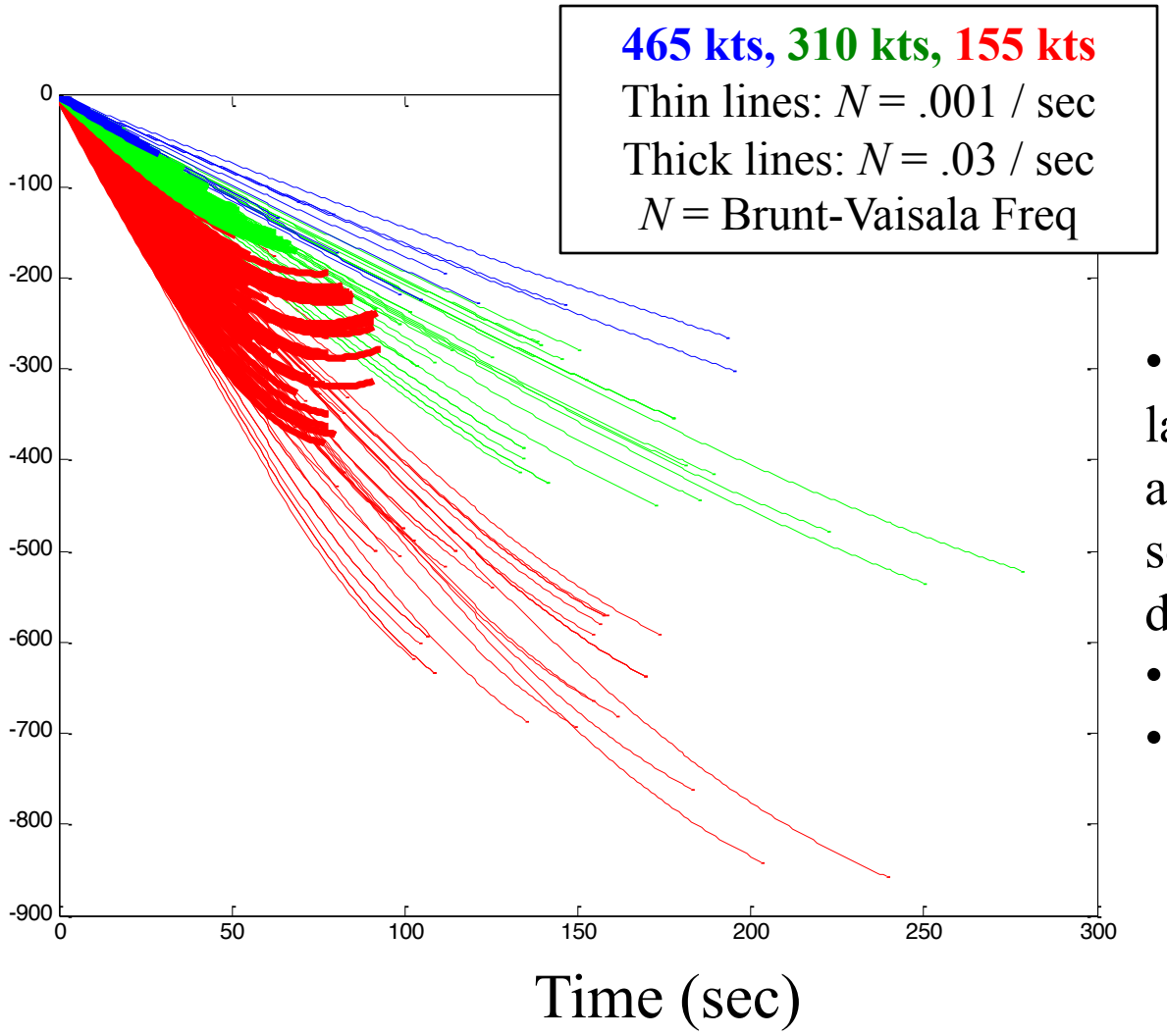
Preliminary Observations

- Common source of wake alerts: Ascending / descending traffic to / from different / same airports
- Other problems also observed: merge of flows
- Analysis of more data / airports will refine conclusions.

Wake Area



- Weight (max. landing weight) and wingspan from set of flights in one day of PDARS data
- TDAWP model
- $\varepsilon = .0002$

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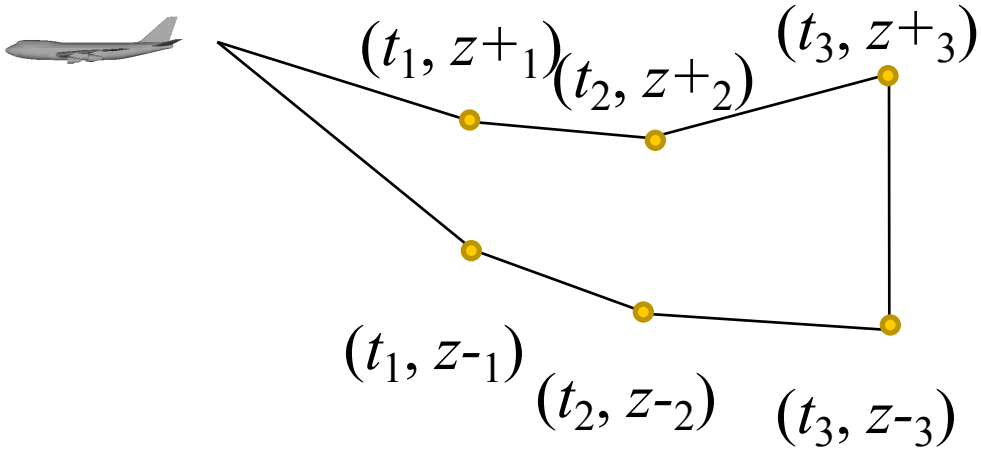
Extensions

- Describe wake area as a 3-D polyhedron
- Polyhedron is a function of:
  - Aircraft: Velocity, mass, wingspan, altitude
  - Atmosphere: Eddy dissipation rate, Brunt-Vaisala frequency, air density, wind speed/direction
  - Circulation threshold



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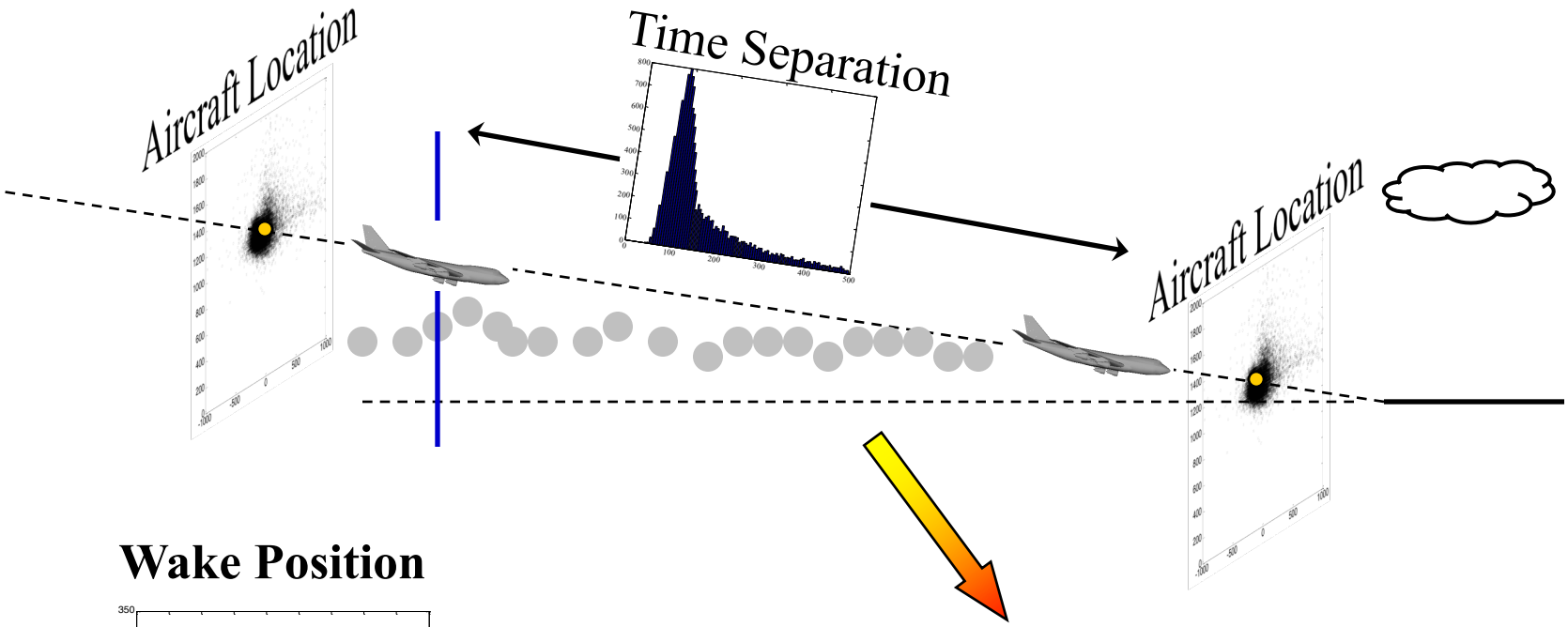
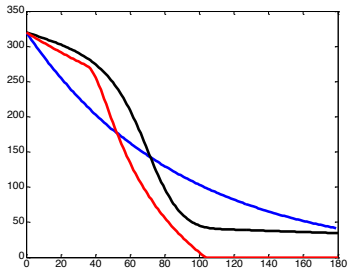
2nd-Order Probabilistic Analysis



Wake Position



Wake Encounter?

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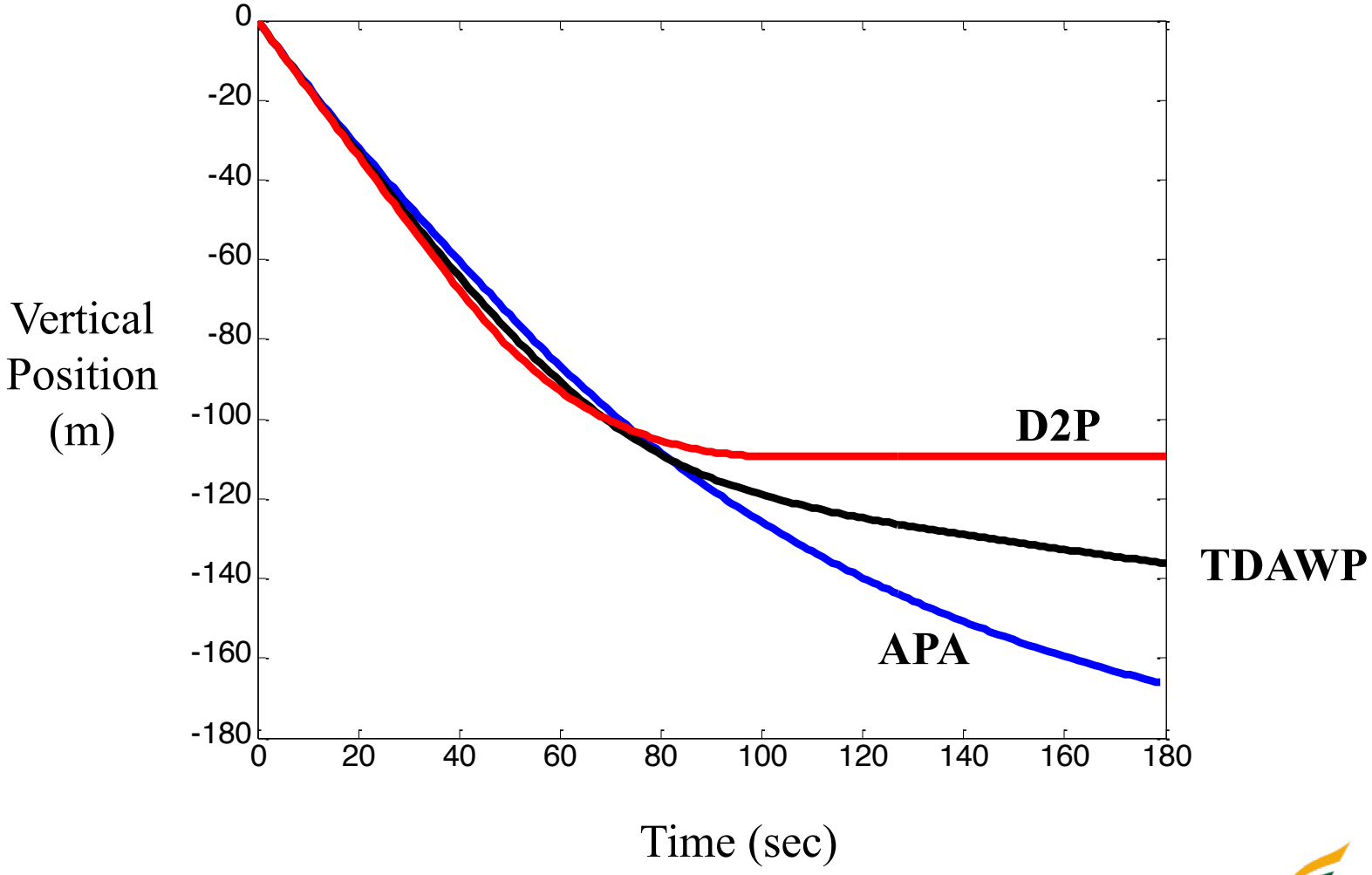
Wake Models Have Differences



Weight = 76,000 kg
Velocity = 65 m/s = ~135 knots
N = 0.0 / sec

Wing span = 38 m
Height = 1,000 m
$\varepsilon = 0.001\ m^2 / s^3$

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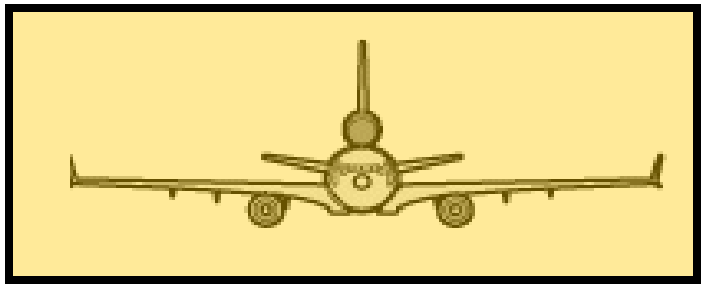
Arrivals at DTW, Single Runway

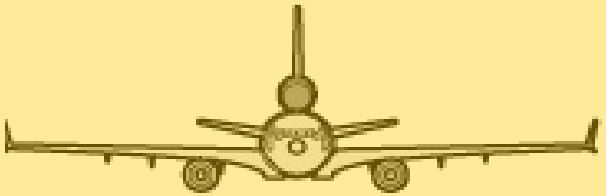
Wake Encounter

Sample result
$\sim 10^{-4}$



Wake Alert

Sample result
~.003



Results using TDAWP, DTW multilateration data,
$\varepsilon = .001\ m^2/s^3$, $N = 0$/sec, Circ > 70 m^2/s

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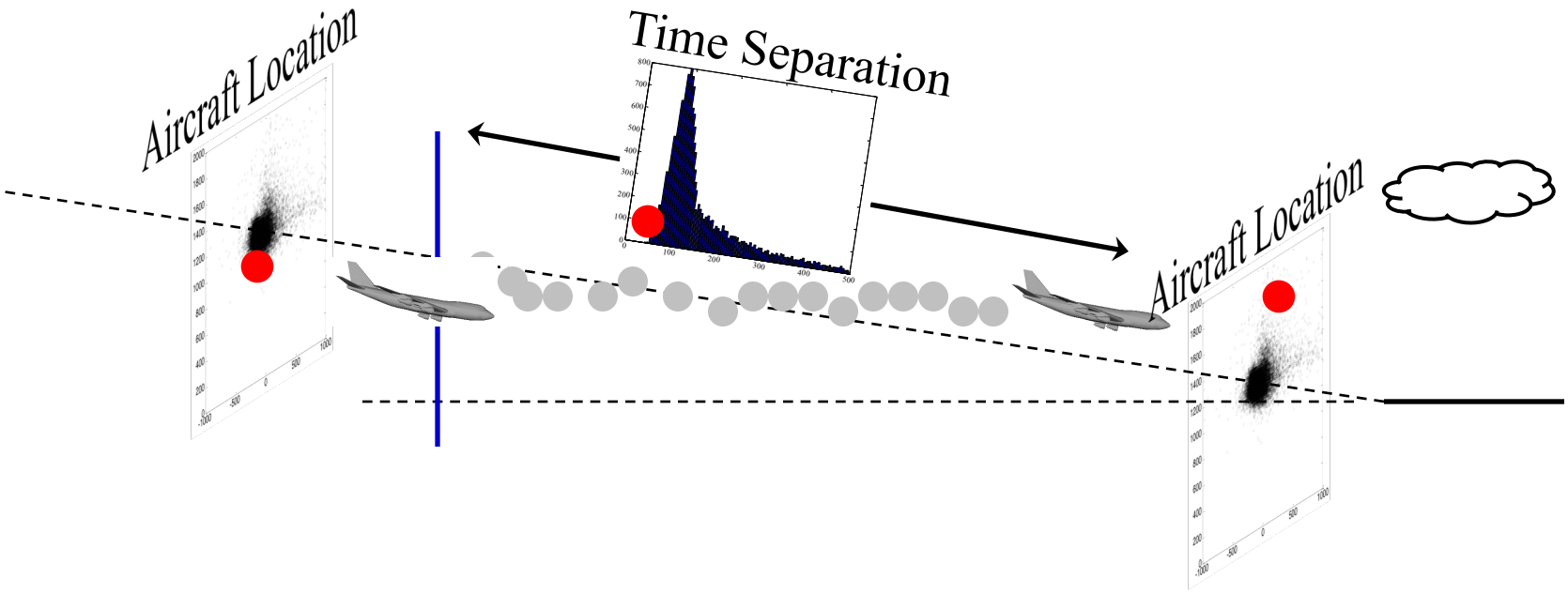
“Typical” Wake Encounter



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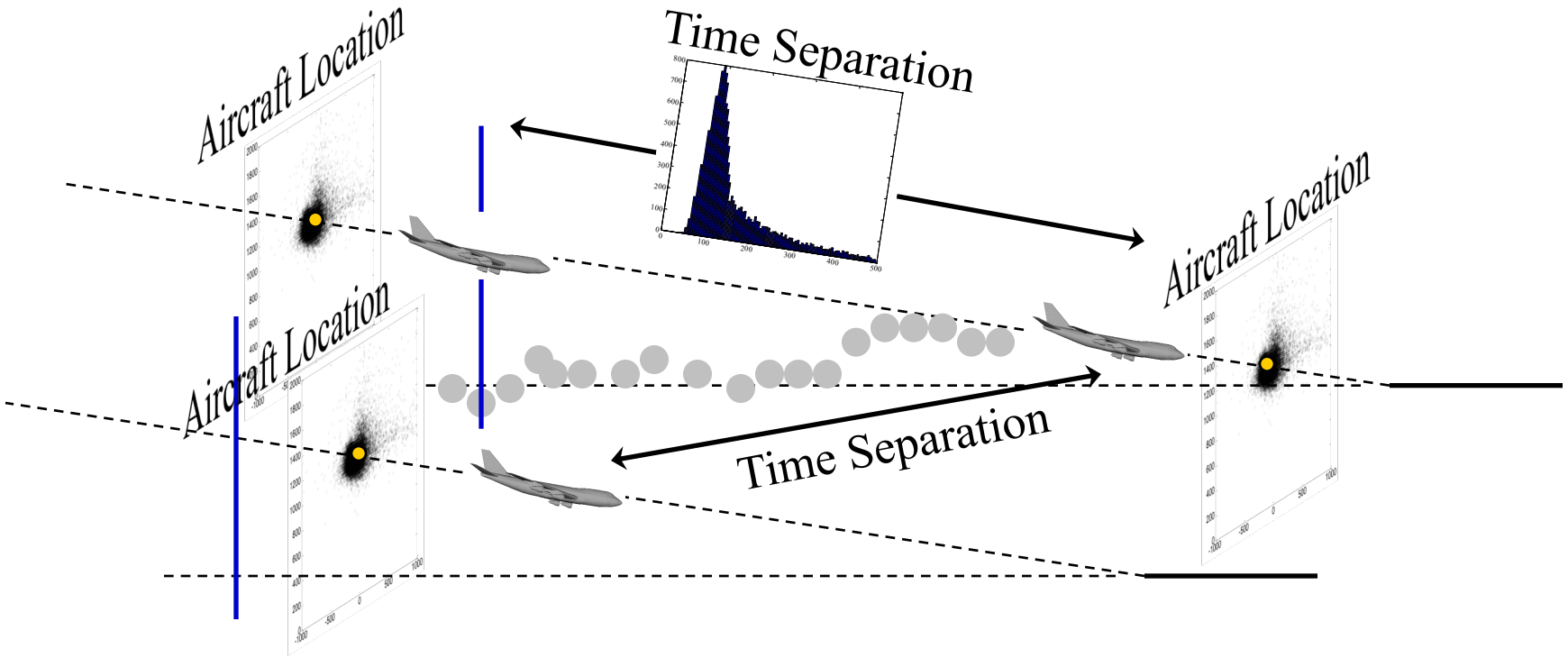
Closely Spaced Parallel Runways



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Summary

- Initial analysis identified several wake-related issues in NextGen: CSPR's, tight routes in transition airspace
  - Analysis of track data helps to confirm / prioritize issues
- Wake encounter models in development to assess relative wake encounter probabilities (NextGen vs. baseline)
  - Probabilistic location of airplane (either via historical data or simulation models)
  - Probabilistic location of wakes (either via wake regions or wake point models)

NEXTOR Ping-Pong Tournament

	NEXTOR Inaugural "Fun" 5K	NEXTOR Ping Pong Tournament
Required number of miles to run	3.1	0
Ambient wind speed	40 kts	0

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Questions?

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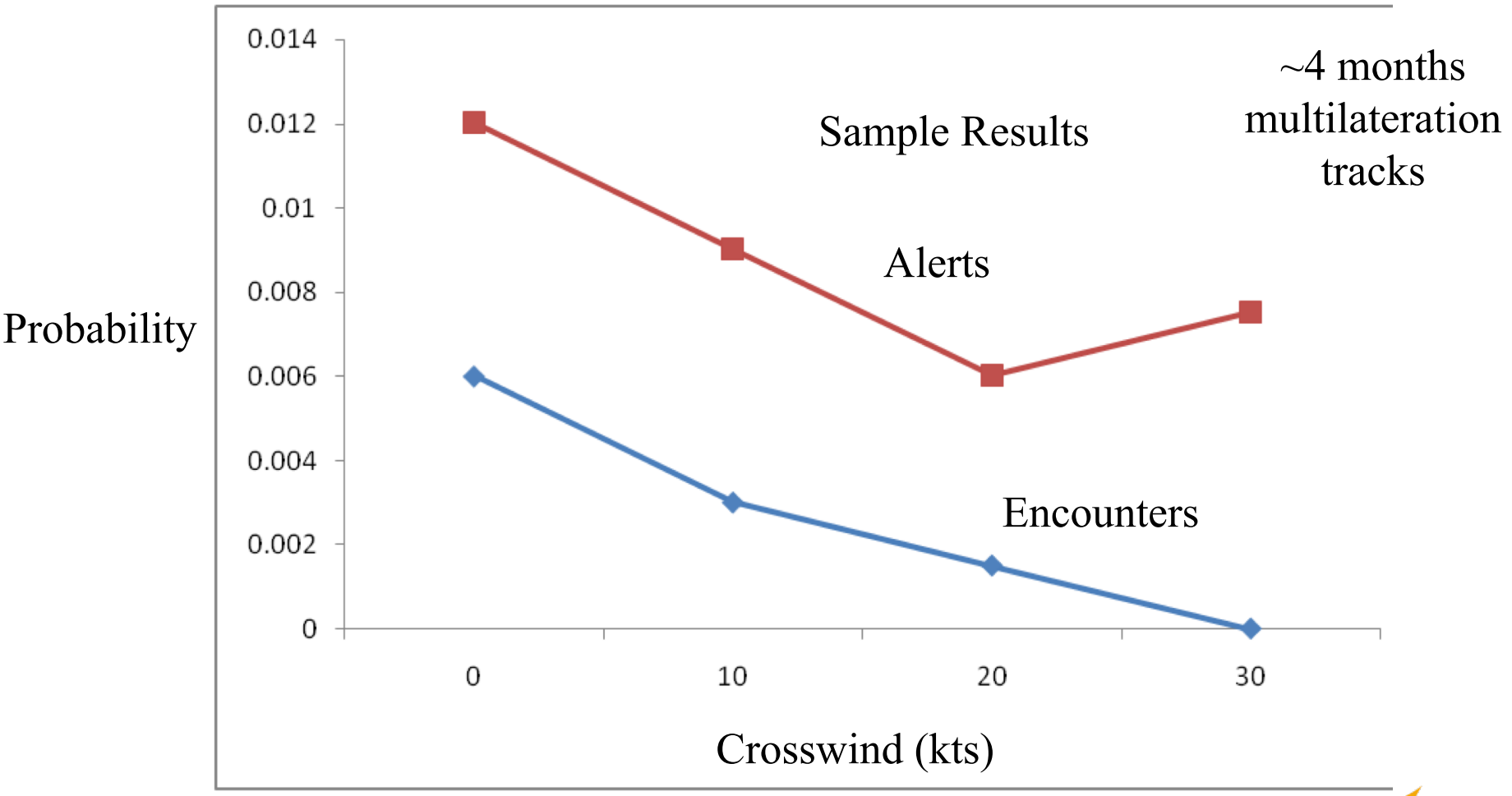
Simplifying Assumptions

- Wake area has constant dimensions
  - No dependence on weight, velocity, wind, etc.
- Wake area is rigid
  - Does not “curve” if airplane turns; “snaps” with airplane movement
- Alerts near airports are discarded
  - Otherwise, heuristics count wake alerts for aircraft on the runway.

Task 1 Summary

- Reviewed NextGen Conops 2.0
- Identified elements with potential wake vortex concerns
- Two critical areas emerged
  - Closely spaced parallel approaches
  - Tight routes and transition airspace

Sample Results



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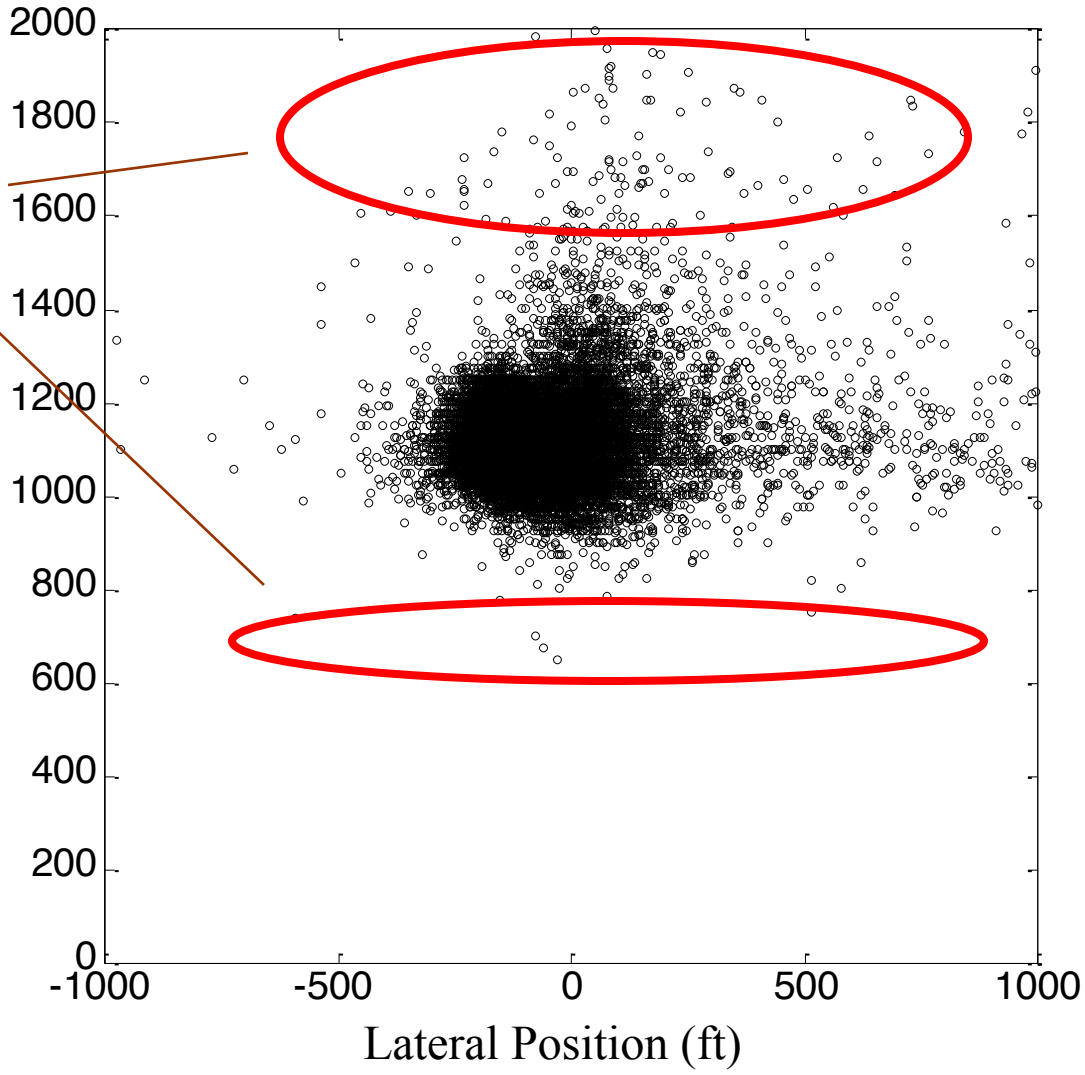
Flight Tracks (3 nm)

Possible safety concern



Data source: DTW 21L, ~22,000 landings, Nov, Dec 02, Apr, Jun, Jul, Aug 03

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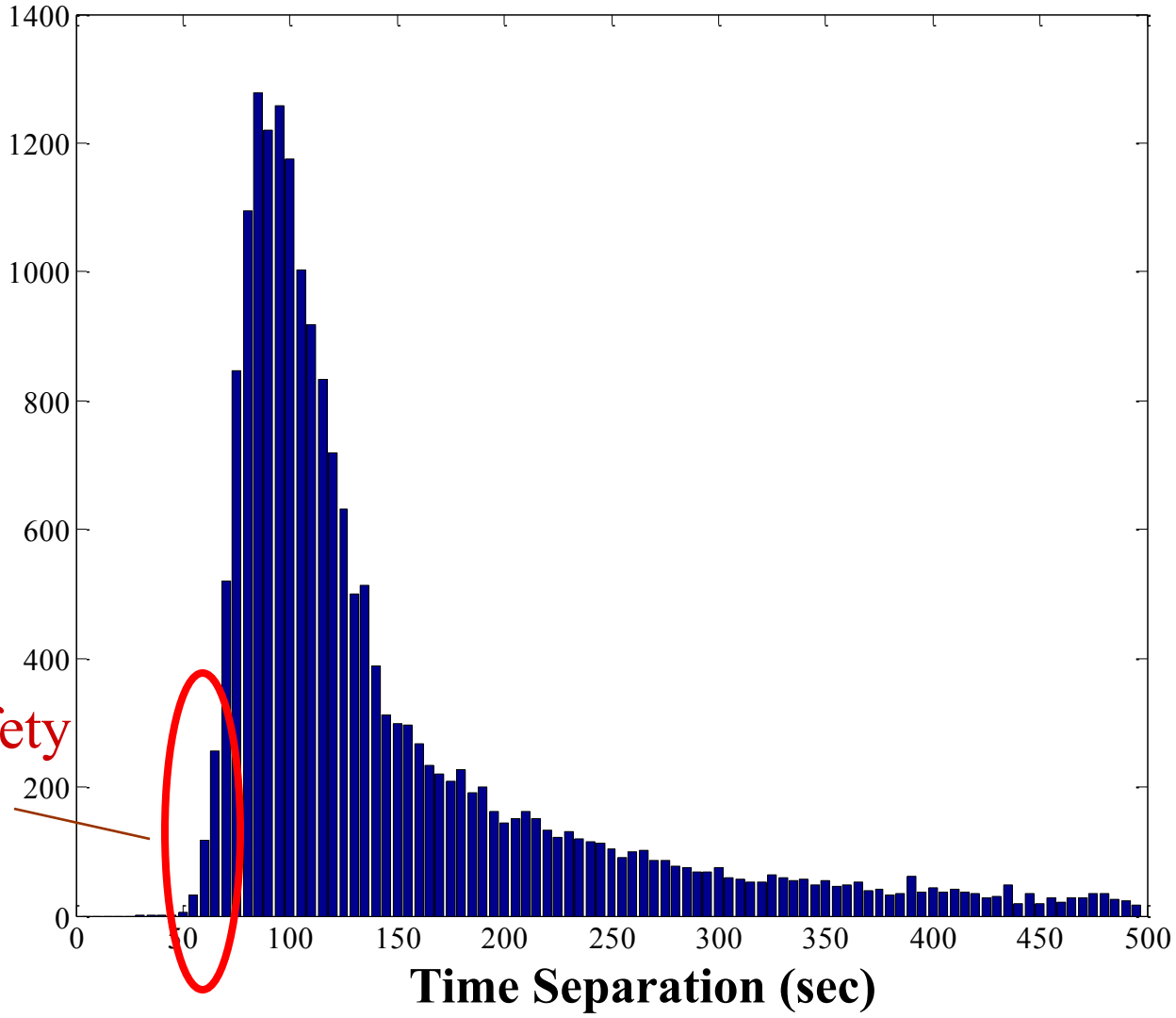
Time Separation (at 3nm)



Possible safety concern

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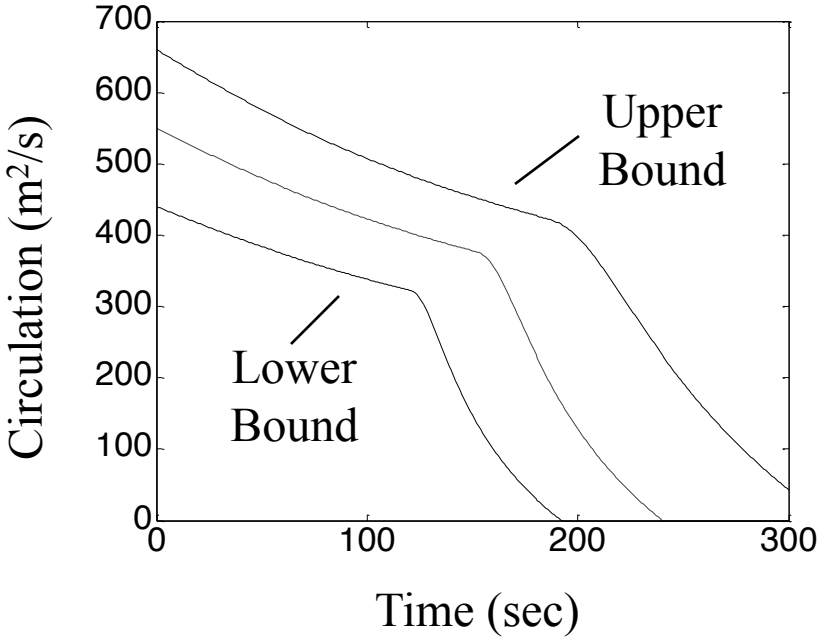
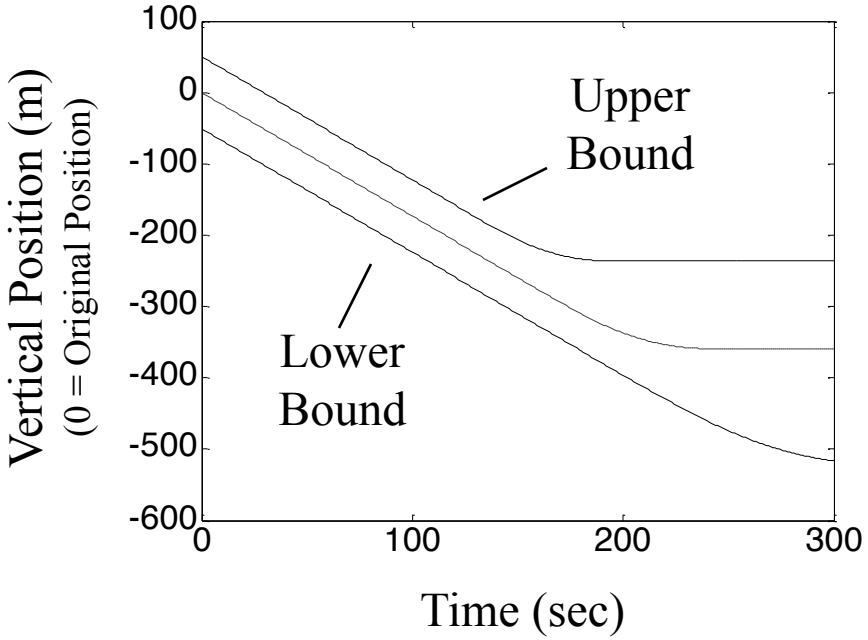
Models with Bounds

Bounds on location and strength





Holzapfel, F. 2003, Probabilistic two-phase wake vortex decay and transport model, *Journal of Aircraft*, **40**(2), 323-331.

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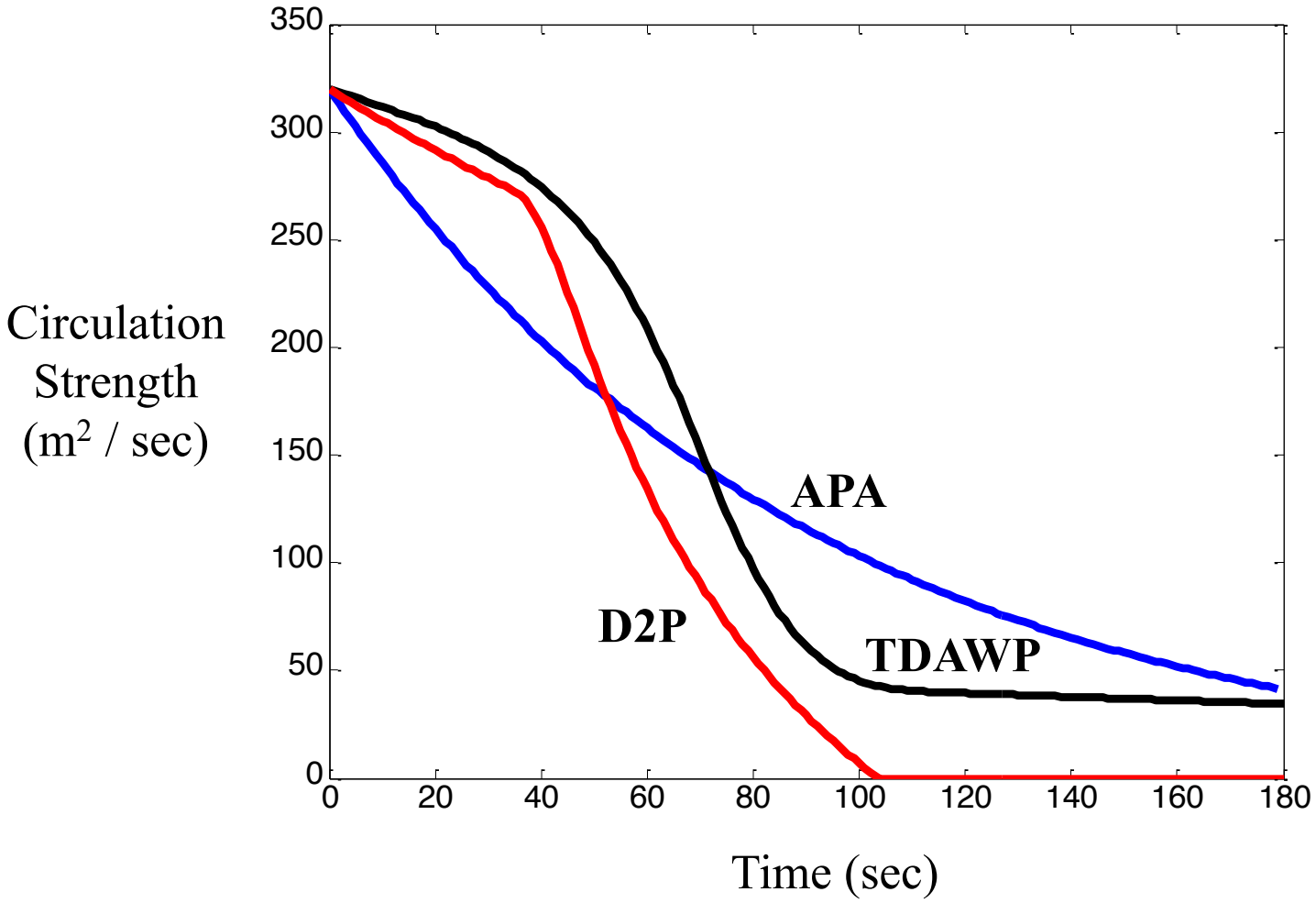
Sample Output: Circulation



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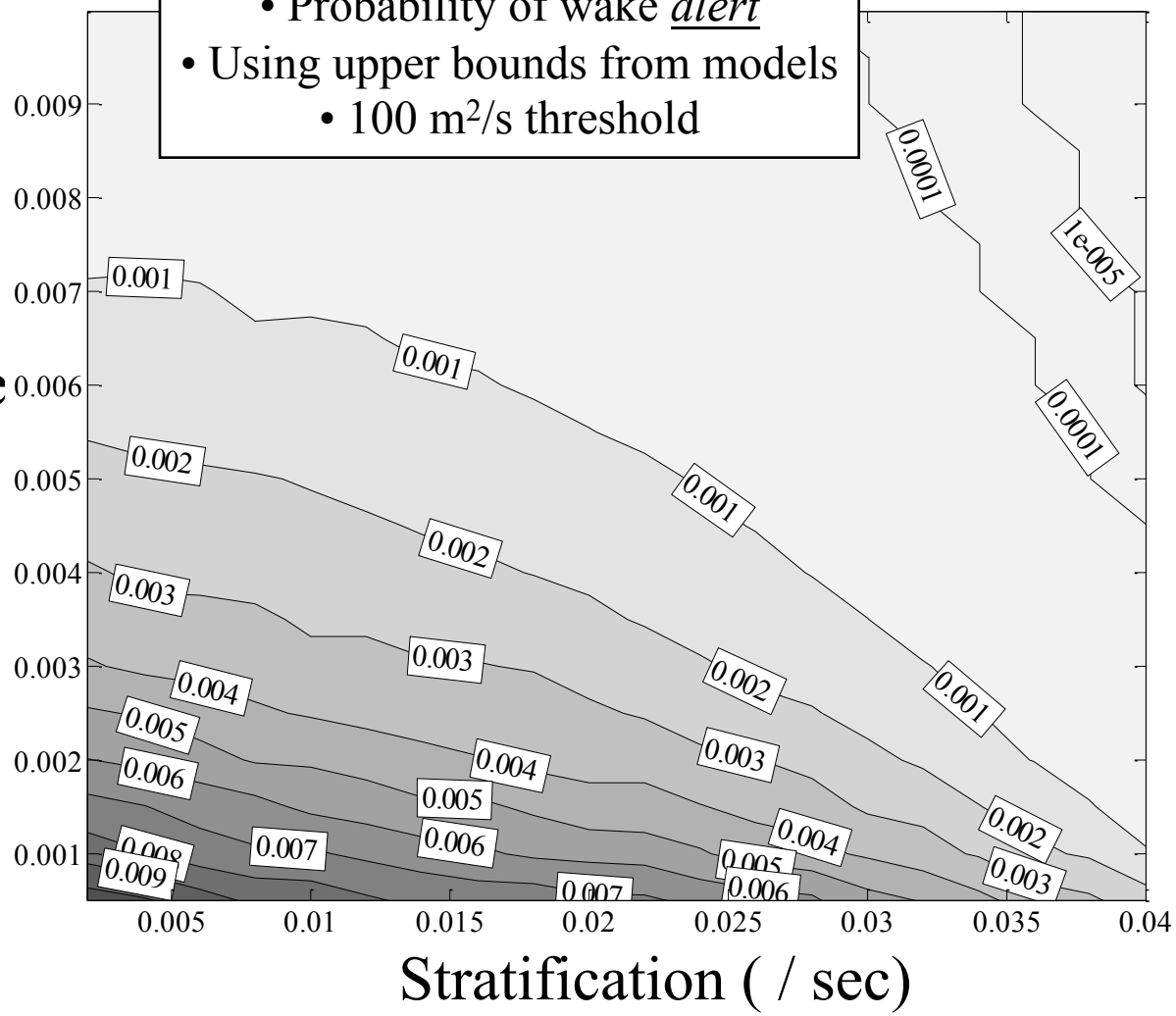
Effects of Atmospheric Parameters

- TDAWP
- Probability of wake *alert*
- Using upper bounds from models
- 100 m^2/s threshold



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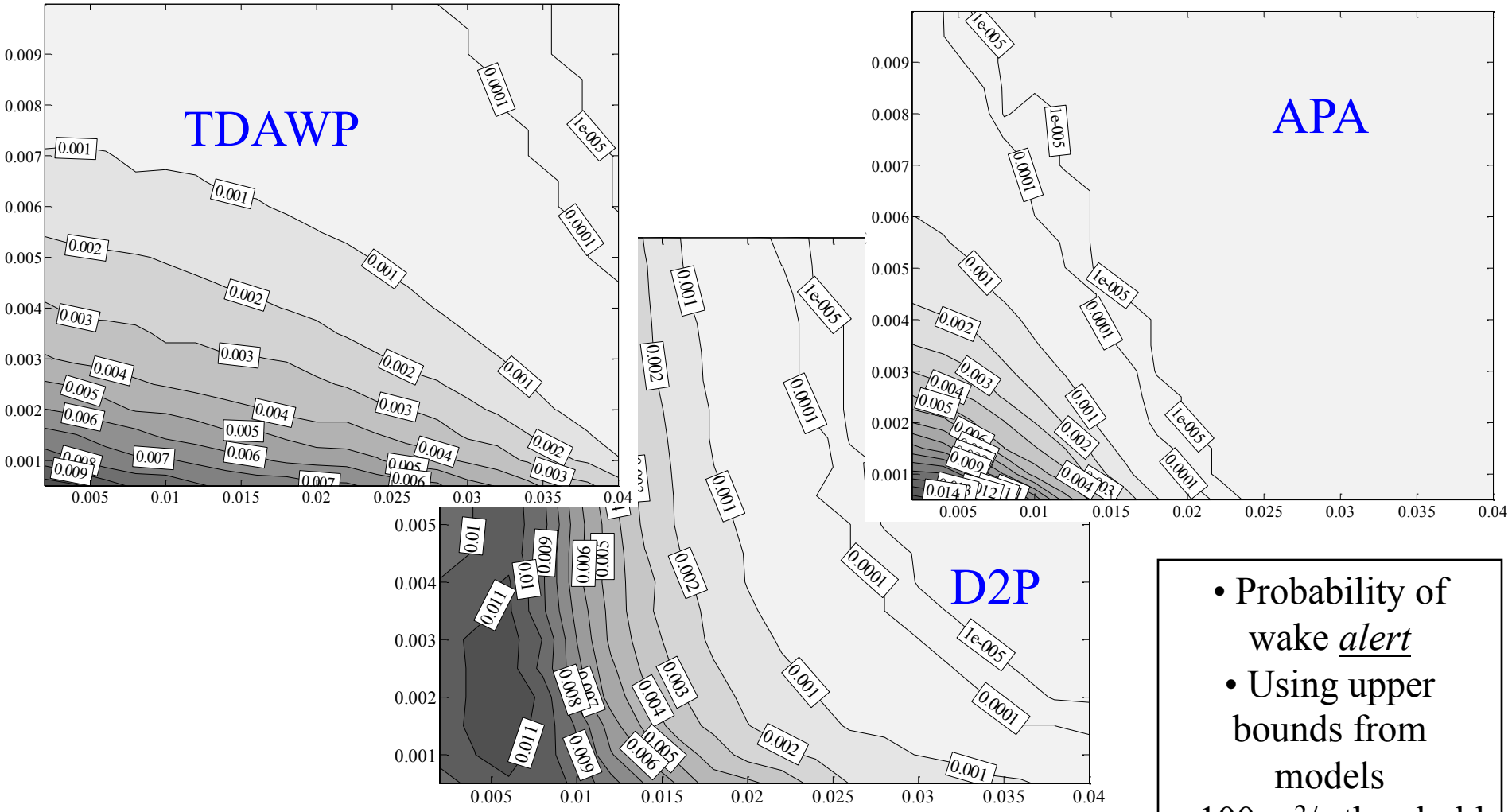
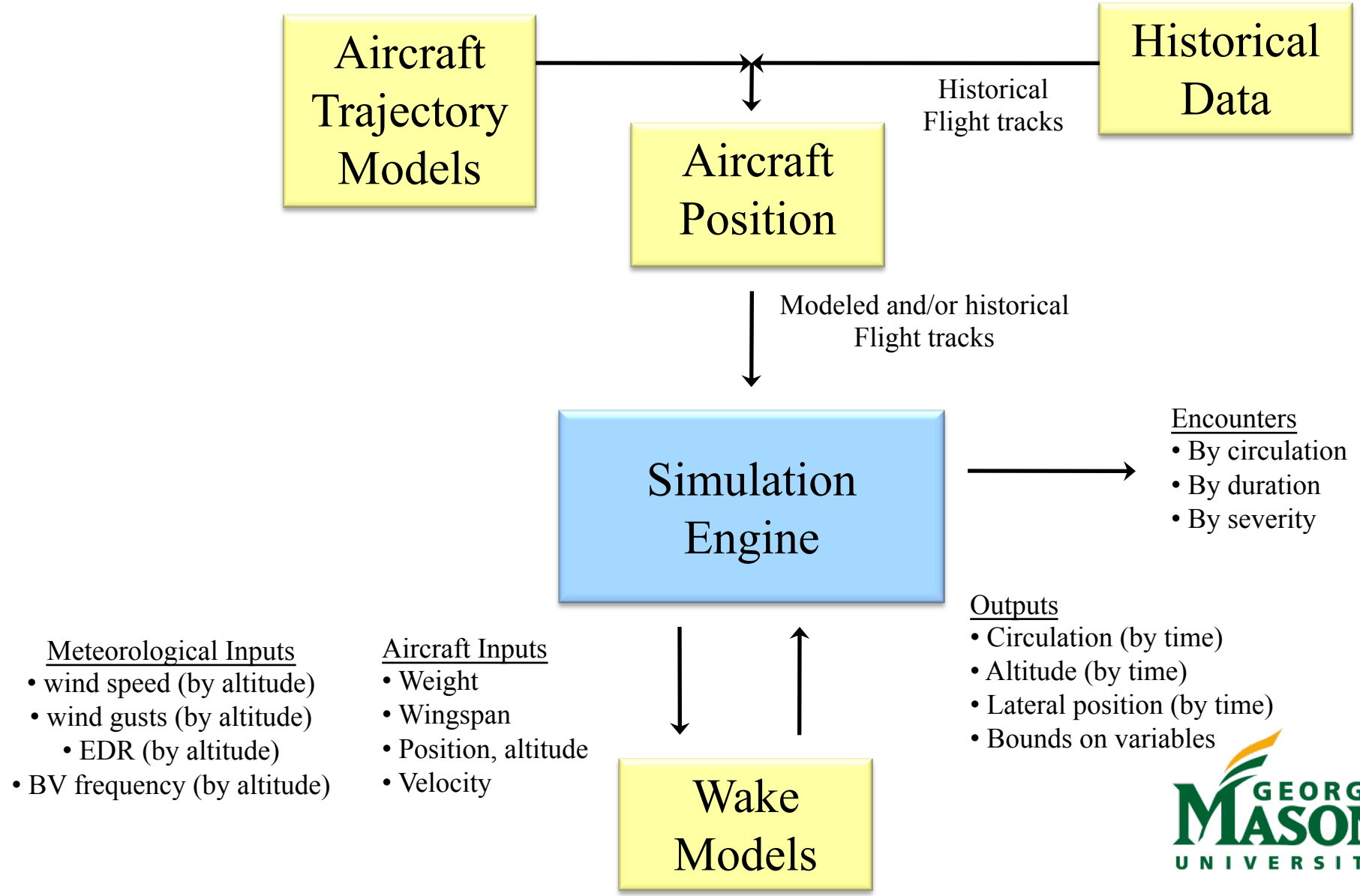
Comparison of Models



- Probability of wake *alert*
- Using upper bounds from models
- 100 m²/s threshold

Data source: DTW 21L, ~22,000 landings, Nov, Dec 02, Apr, Jun, Jul, Aug 03

Some Elements of Wake Analysis

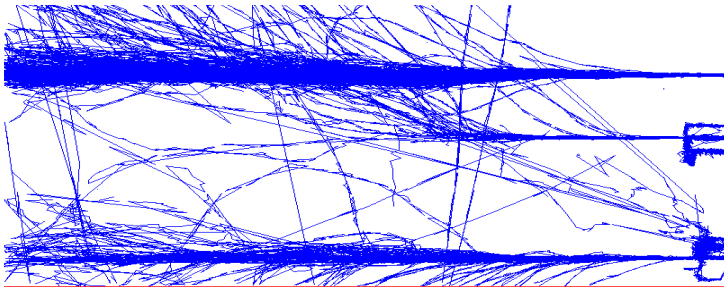


Project Summary

- Task 1: Examine the NextGen Concept of Operations and determine what parts (if any) of the concept would cause an increased risk of an aircraft encountering a wake turbulence hazard
- Task 2: Research questions, mitigations, and prioritization of wake hazards
- Task 3: Develop model of current operations for use as a modeling baseline in studies of future NextGen era operations
- Task 4: Assessment of relative wake turbulence encounter probability associated with NextGen scenarios

Analysis Scenarios

- Parallel routes



- Non-parallel routes

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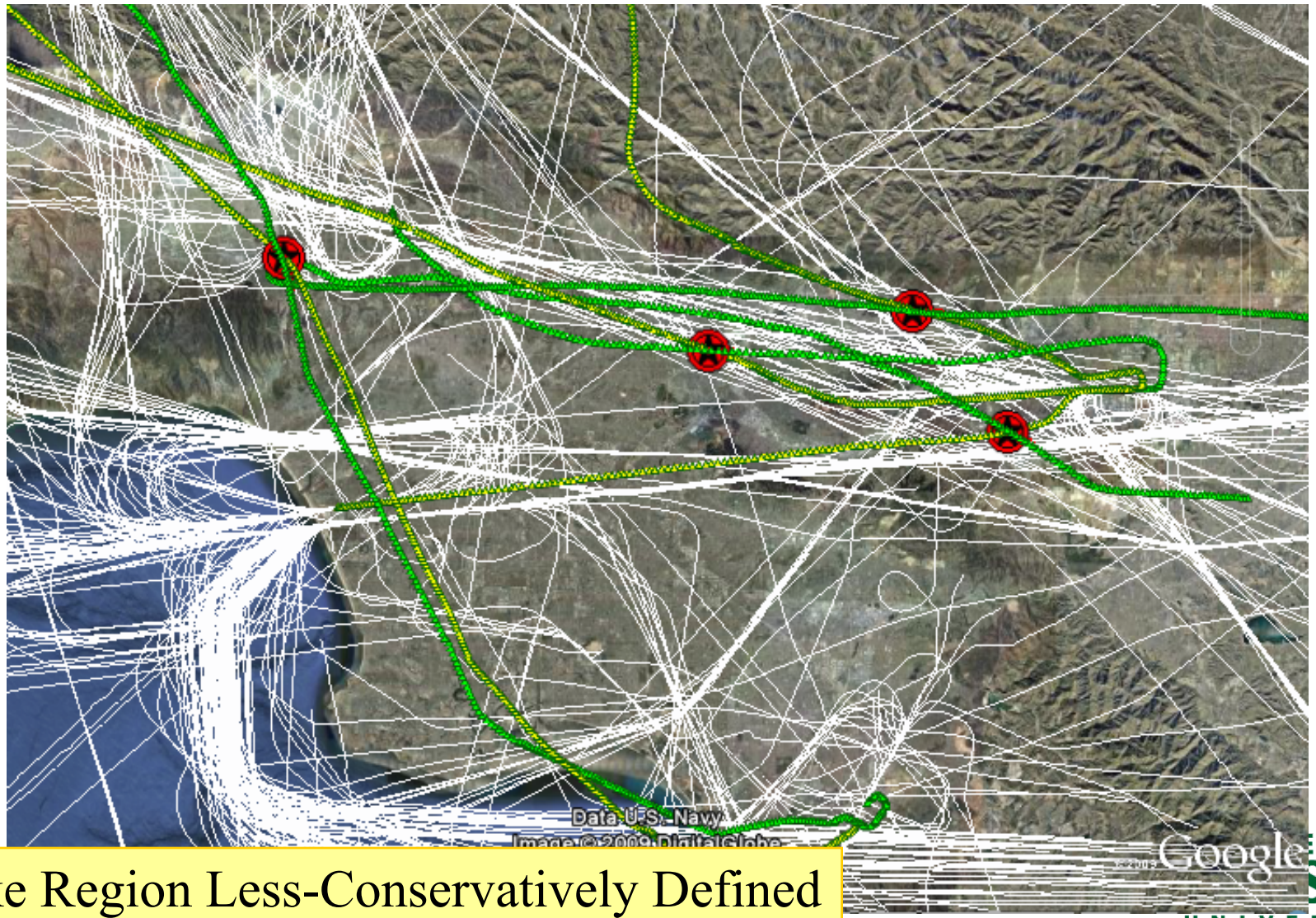
All Wake-Alert Tracks, 1 Day



Wake Region Less-Conservatively Defined

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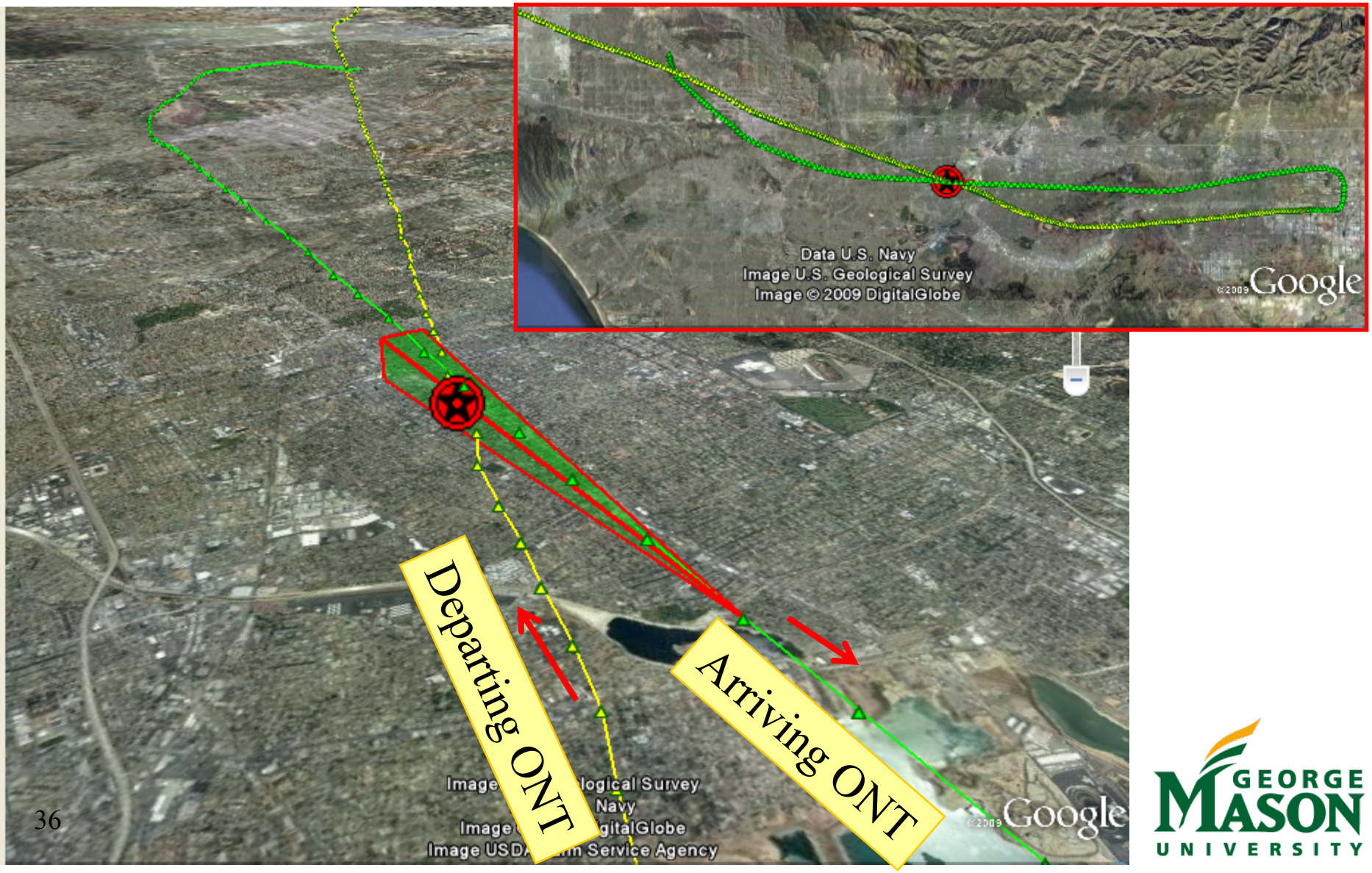
Sample Wake Alert



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Sample Wake Alert

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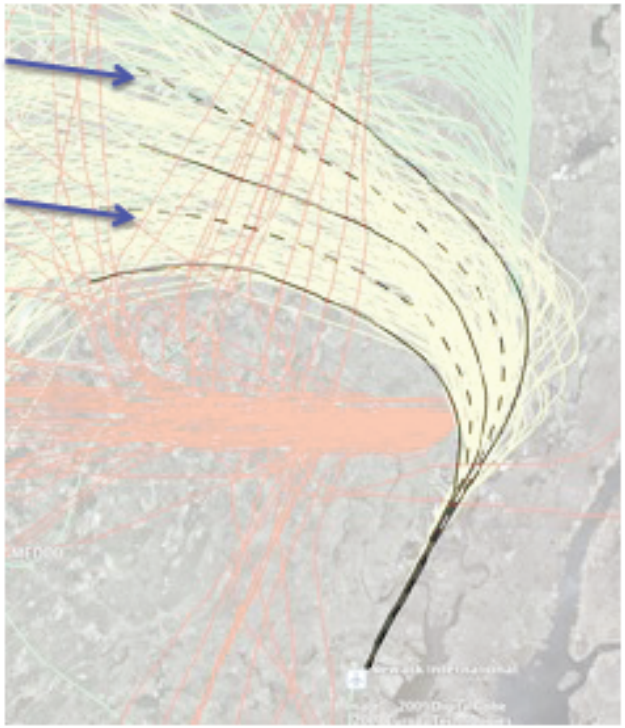
Potential NextGen Operation

- **RNP approaches may allow simultaneous approaches to the 22s using more tightly defined routes over TEB.**
- **Due to the tight airspace over TEB spacing for the CSPAs would have to occur further from the airport than it does today.**



Split current single runway approach procedure into two simultaneous RNP approaches?