Identification of Wake Vortex Issues in NextGen

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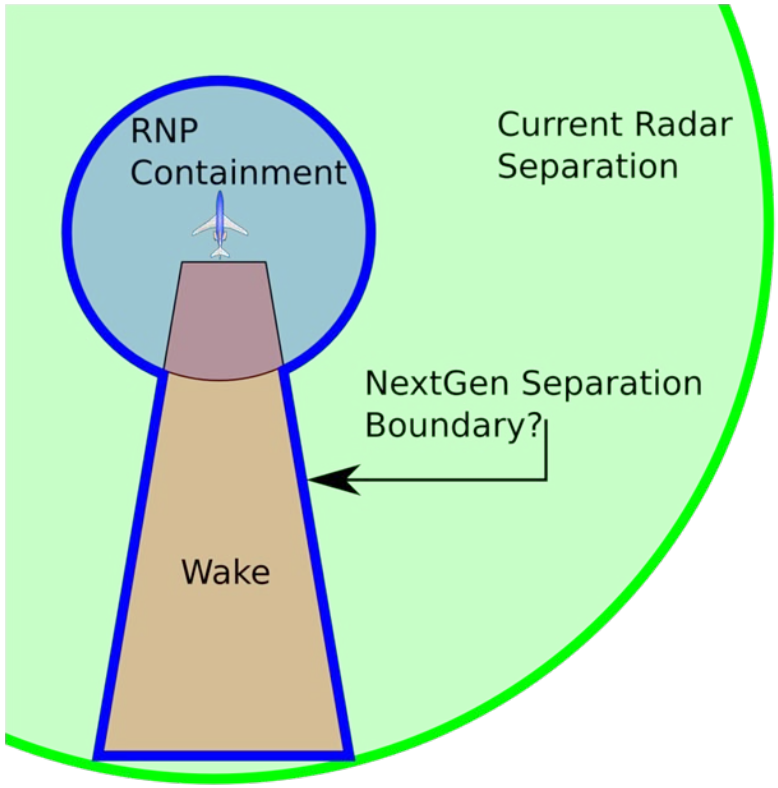
Objective

- Tasked with identifying NextGen operational concepts that may pose an increased risk of an aircraft encountering wake turbulence
- The results of this analysis add to the breadth of work assisting NextGen planners in identifying where wake vortex constrains need to be considered
- The results also feed a more detailed wake modeling effort being undertaken with Virginia Tech and George Mason University

Analysis Method

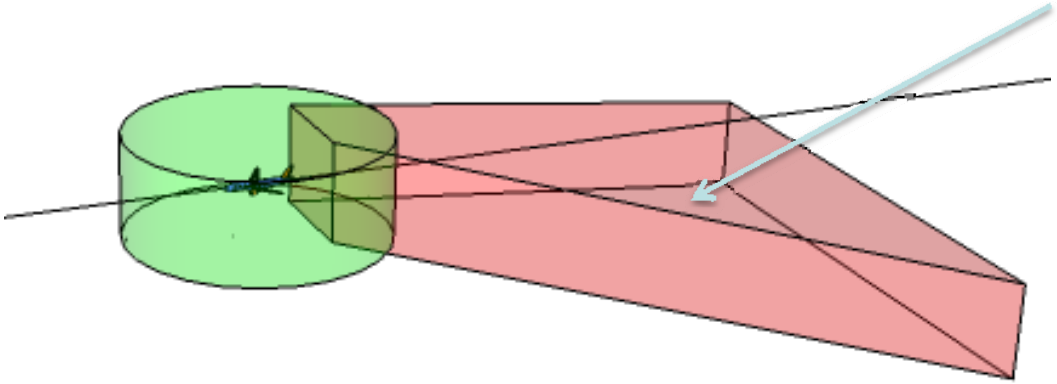
- Reviewed:
  - NextGen Concept of Operations (ConOps) v2.0
  - NextGen Integrated Work Plan (IWP) v1.0
  - NextGen Implementation Plan 2009
- Listed all concepts that cause aircraft proximities or geometries that have the potential for wake vortex interaction
- Interviewed individuals involved in developing NextGen to determine their perception of potential wake vortex hazards or issues
- List has been updated as new information has become available
- Seeking further input

Precision Navigation Separation Requirements



- NextGen will use precision navigation and surveillance technologies (e.g. RNP, ADS-B) which is expected to enable reduced separation
- Current radar separation rules are on a similar scale to the wake hazard
- Aircraft wakes may no longer be buffered by navigational separation requirements
- NextGen separation requirements could look substantially different to those currently in use

Separation Rule Complexity



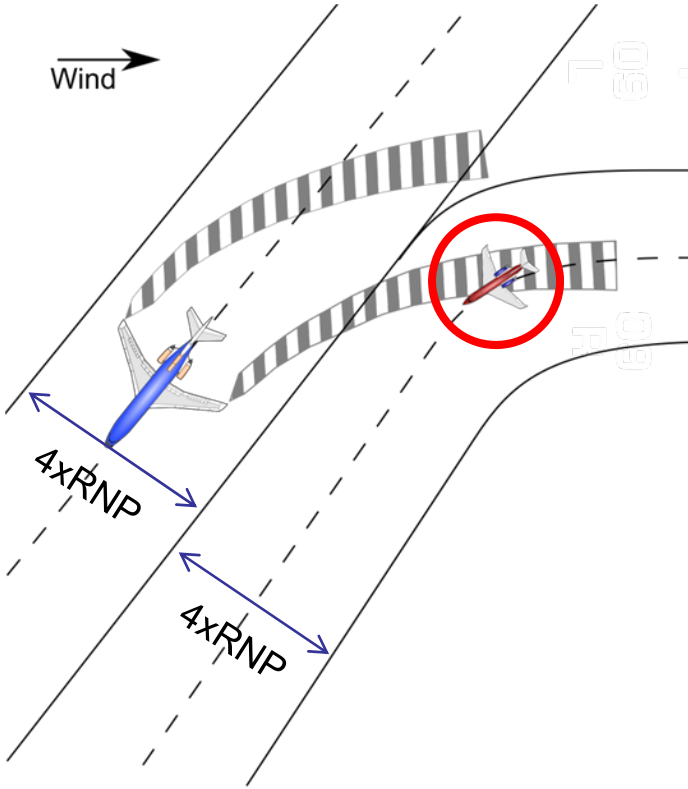
Dynamic wake separation boundary could vary with:

- Wind velocity and/or direction
- Lead aircraft weight/configuration/velocity
- Trailing aircraft weight/configuration/velocity
- Atmospheric conditions (aside from wind)

- Wake separation standards could be complex
- With improved wake models and atmospheric/aircraft data, tightly defined wake hazard boundaries may be possible
- Increased complexity in separation criteria could make controller or pilot workload unacceptably high
- A balance must be found between increasing airspace utilization and managing the complexity of procedures

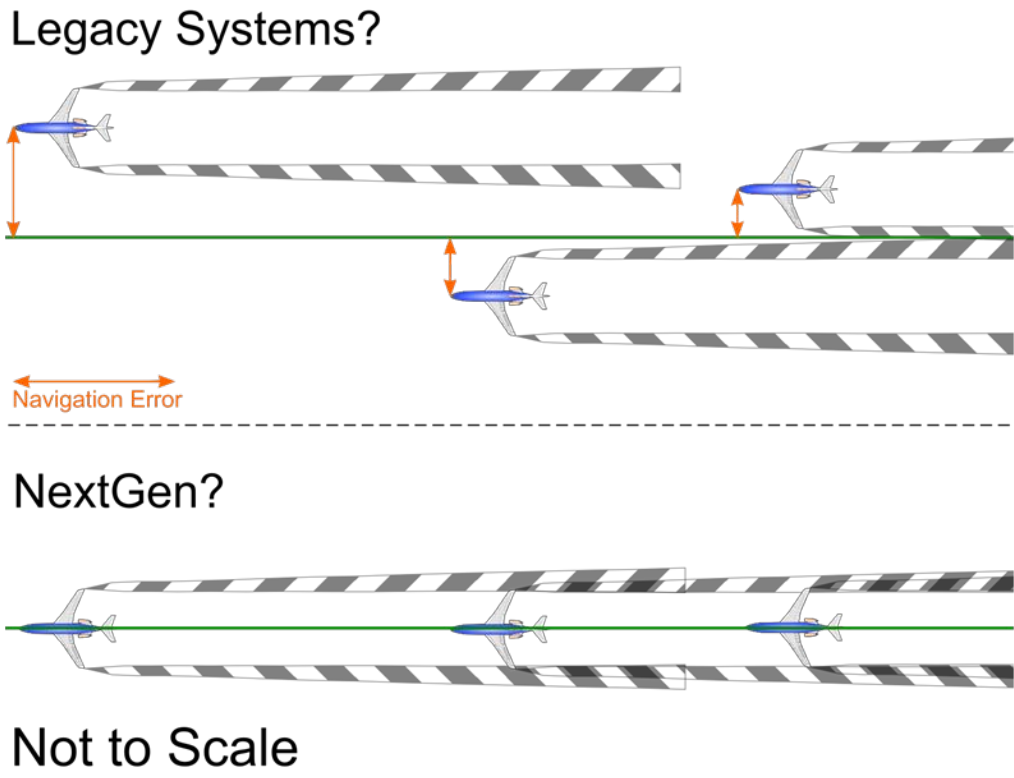
Tight Routes

- NextGen will use precision navigation to improve capacity and will increase airspace utilization by reducing the separation between adjacent routes
- If the current 4xRNP segment width is used, the required separation between routes may be as low as 0.4nm (for RNP0.1)
- Tightly-spaced routes increase the risk of wake vortices from one route propagating into adjacent routes
- Wake vortex separation criteria may become the determining factor in route separation



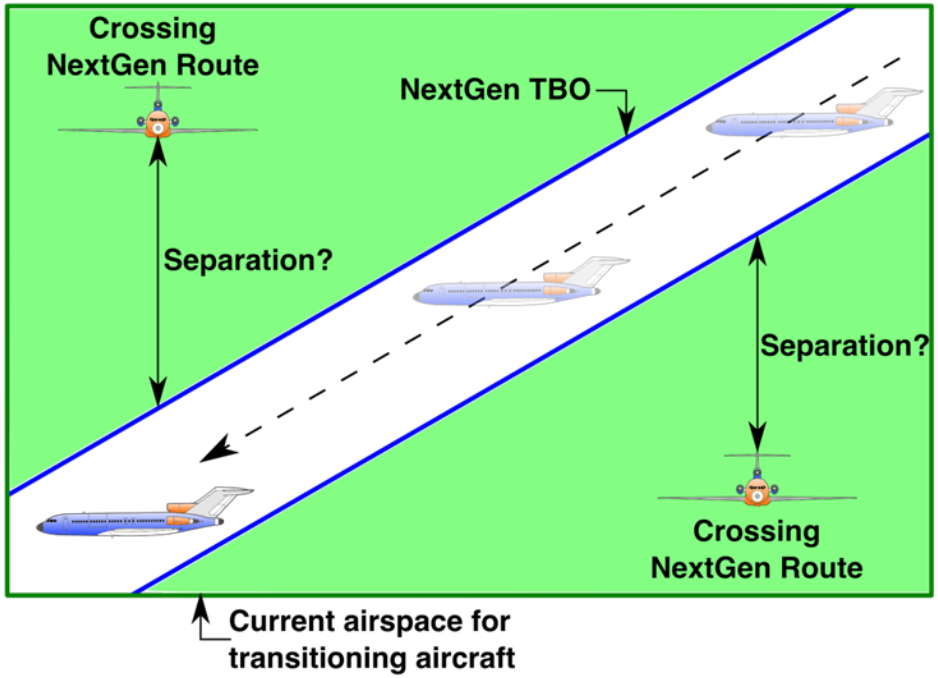
Precision Navigation

- Navigational imprecision may provide some protection from wake vortices
- NextGen aircraft will follow assigned flight tracks more precisely, potentially increasing the risk of a wake encounter for climbing and descending aircraft
- Strategic lateral offset procedures (SLOP) are currently being used in part to move aircraft out of the wake of preceding aircraft



Trajectory-Based Operations

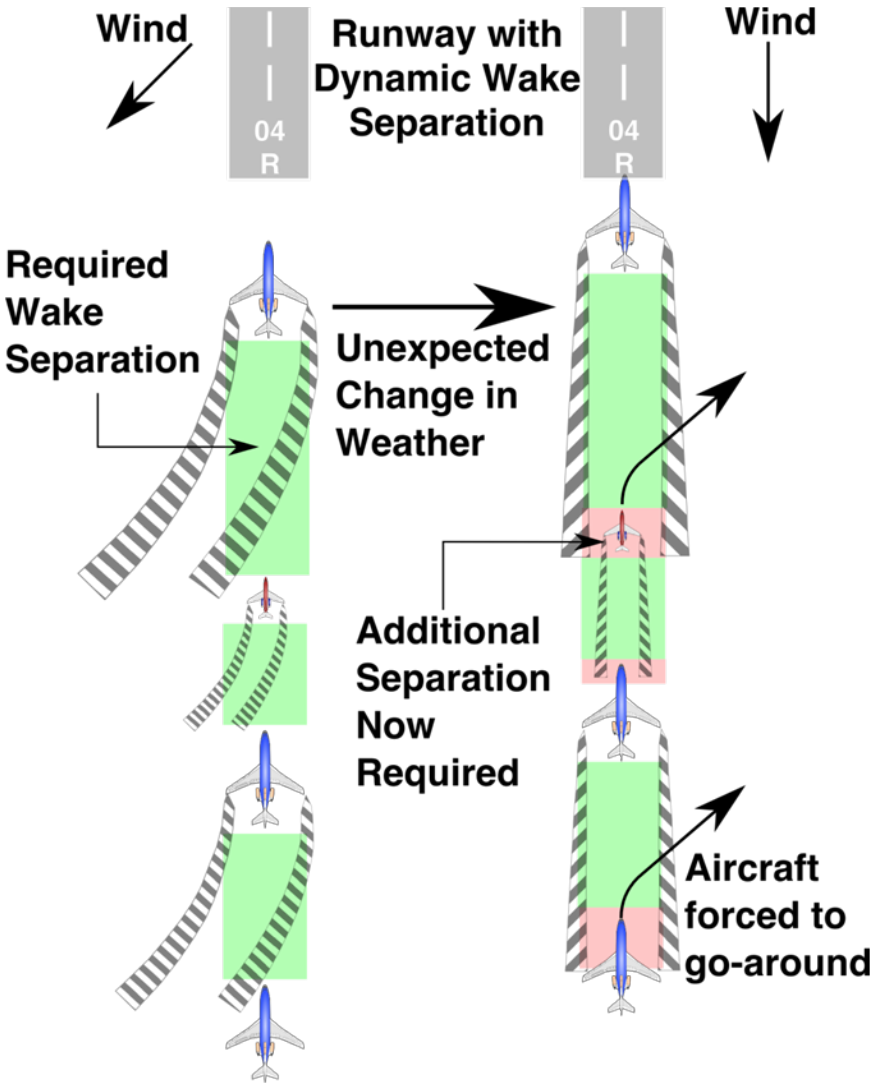
- Many of the aircraft operating in NextGen will be following precisely defined 4-dimensional trajectories (4DT) through transition airspace.
- Transitioning aircraft are currently given a large volume of airspace for maneuvering
- TBOs will require a detailed understanding of wake position and evolution in all three dimensions in order to plan close-proximity safely separated flights



- **Need to define and determine 4-D trajectory separation criteria between trajectories**

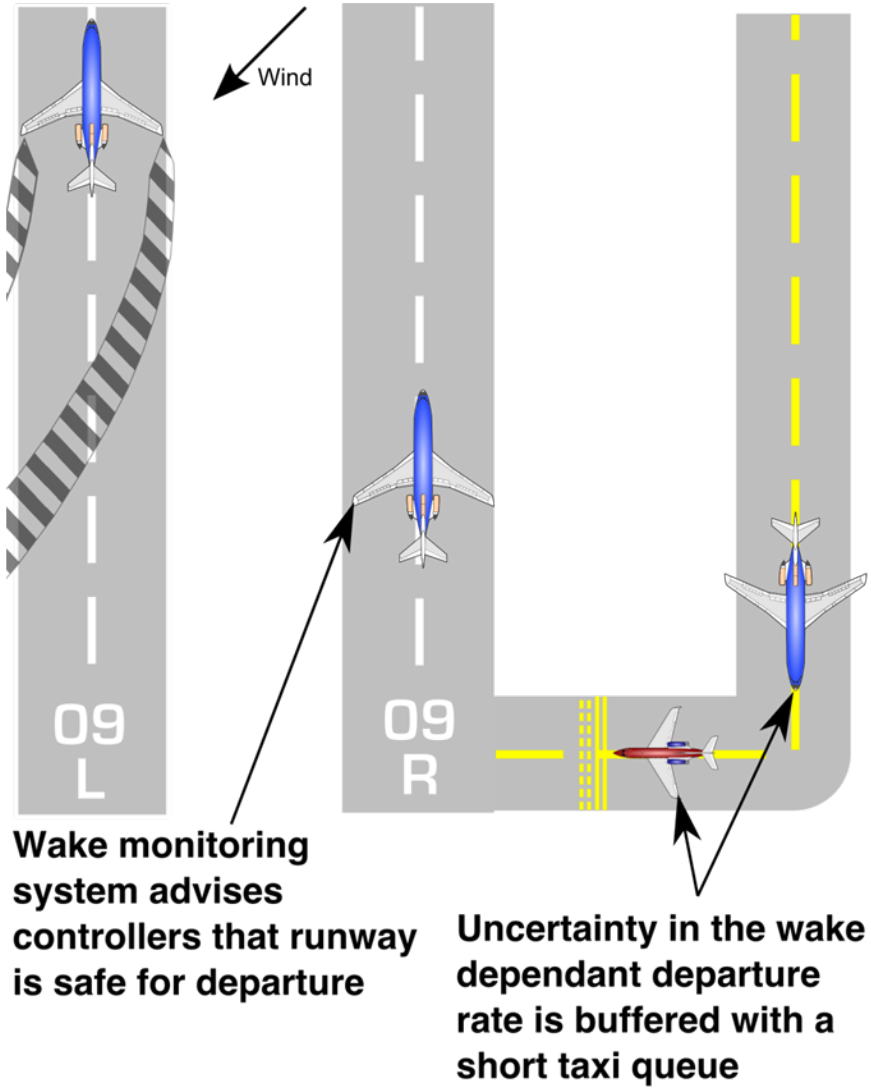
Dynamic Arrival Sequencing

- *"Real-time adaptation of applied separation for vortex mitigation"*
- Disruption to the arrival stream is costly to runway throughput
- A dynamic separation system will have to balance the cost of unexpected separation changes with the cost of buffering for that uncertainty
- The separation requirements will have to be reliably forecast on the timescale of the approach (at least 15-20mins)

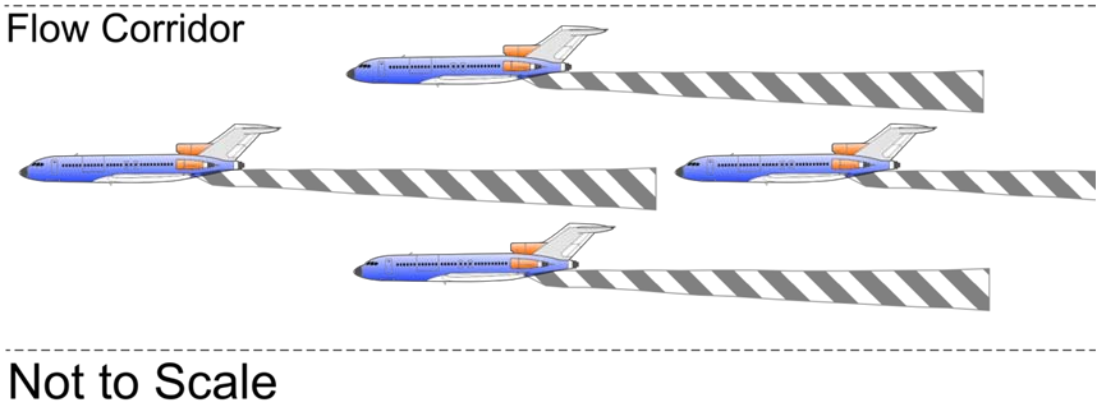


Dynamic Departure Sequencing

- Dynamic departure separation will be easier to implement than dynamic approach separation
  - Aircraft waiting to take-off can tolerate small uncertainty in departure time
- For departures-only single or parallel runways dynamic separation maximizes runway capacity with little risk
- Mixed-use runways will encounter the same issues as dynamic spacing for arrivals



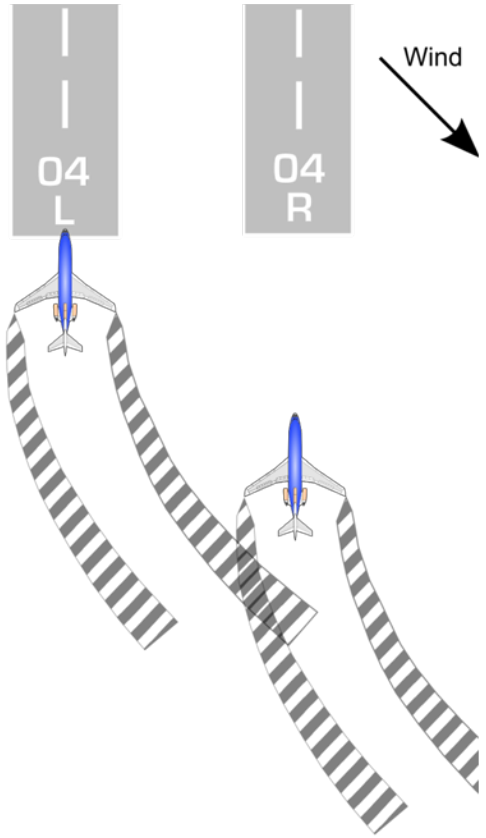
Flow Corridors



- **NextGen is seeking to create flow corridors, comprising “bundles” of parallel high altitude en route trajectories**
- **Wake vortex separation constraints may be the limiting factor in sizing these corridors**
- **Understanding the behavior of wakes generated by high-speed, high-altitude aircraft in clean configurations will be important in safely designing these procedures**

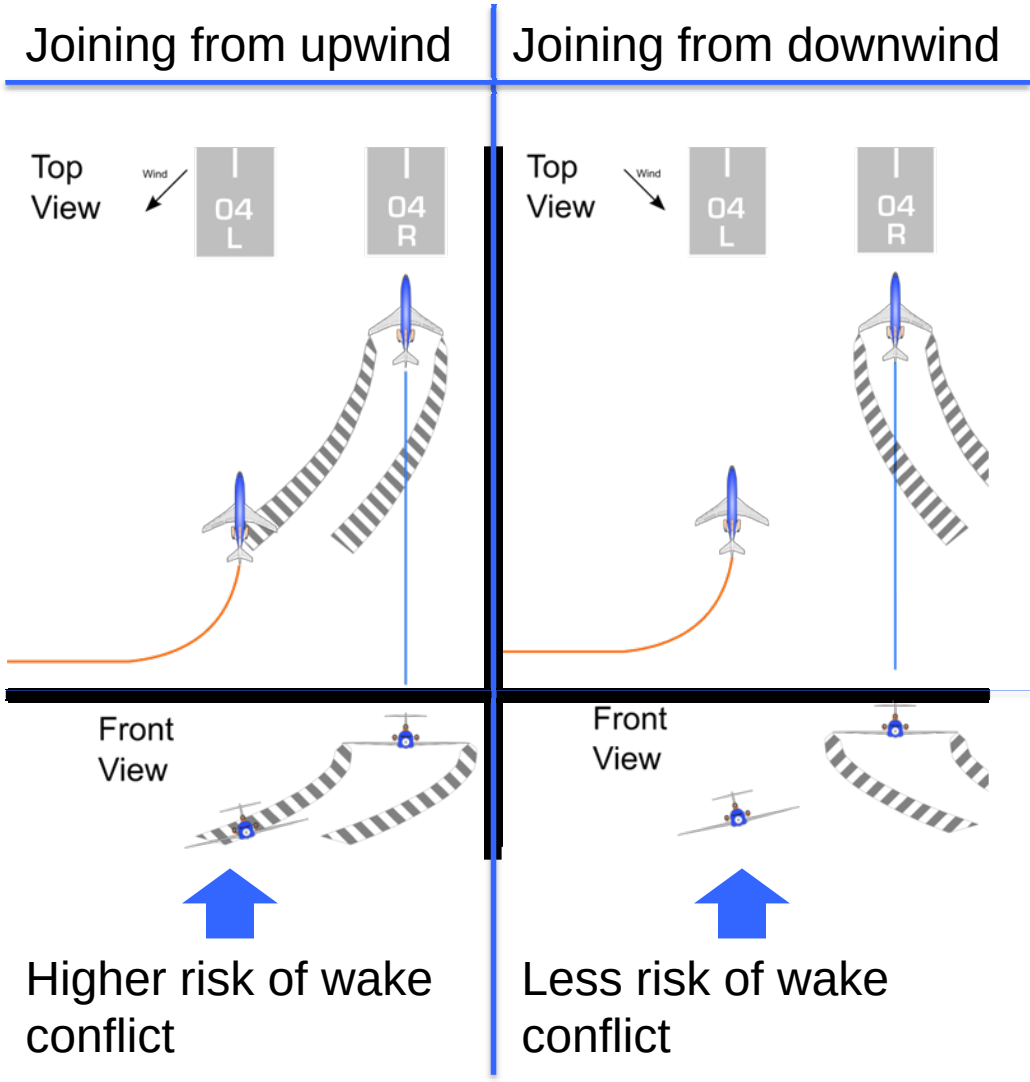
Closely Spaced Parallel Approaches

- A well known but acute problem
- Closely spaced parallel approach improvements under NextGen:
  - Achieve VMC capacity to CSPA under IMC
  - Increase capacity beyond current VMC capacity
  - Reduce separation requirements between CSPR
- At close runway separations dependent approaches seem inevitable
- CSPA force aircraft into tight proximity procedures
- Procedures must protect from wake encounters during routine approaches, and also ensure risk of an encounter is mitigated during blunders and missed approaches



Setting-up CSPAs

- Positioning aircraft onto CSPA may present unique wake issues
- Currently an altitude differential is used to protect against overshoots, this differential may be reduced for closely spaced dependant approaches in NextGen
- This reduced vertical separation may increase the wake hazard
- Practical considerations often limit the flexibility that would be needed to use crosswinds to mitigate this risk



Increased Exposure of Small Aircraft

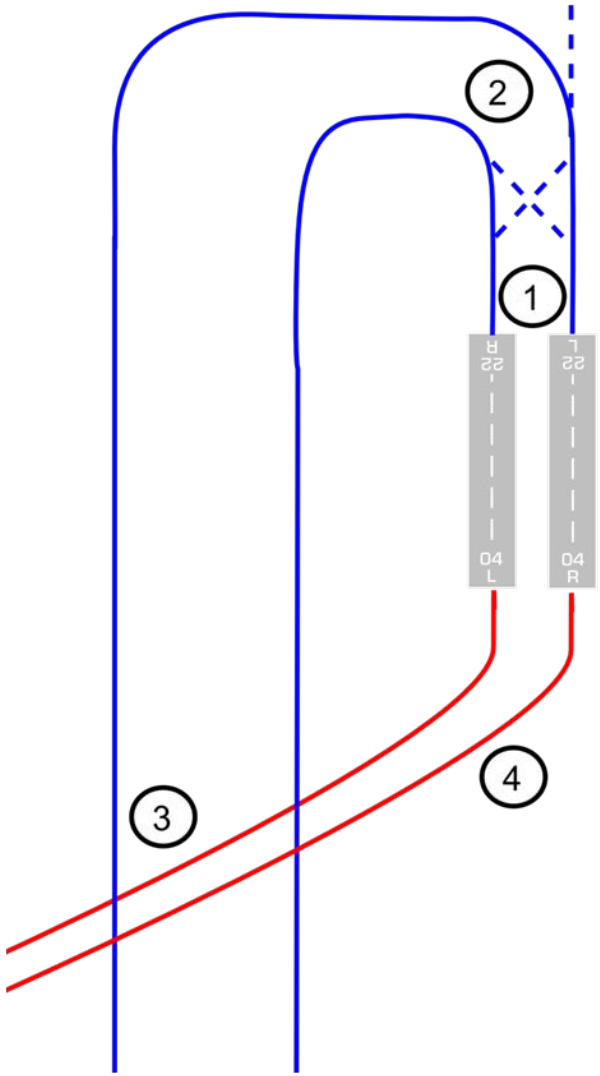
NextGen will accommodate a wider range of aircraft sizes than currently operate in controlled airspace, from tiny VLJs to the large A380.

- Small aircraft (e.g. UASs and VLJs) will be particularly vulnerable to wake vortex encounters given their generally lower weight and, for UASs, potentially reduced situational awareness
- NextGen also seeks to increase accessibility of terminal and high altitude airspace to smaller aircraft types potentially exposing these types to a higher risk of wake encounters

Procedures with the Highest Potential for Wake Issues

Terminal Area Tight Proximity Operations

- The list of wake issues was filtered to identify procedures with the highest potential for wake concerns
- Terminal area tight proximity operations contain most of the wake issues
- Four generic tight proximity operations were identified for further analysis:
  1. Closely spaced parallel approaches (CSPA)
  2. Close proximity arrival procedures
  3. Crossing arrival and departure streams
  4. Close proximity departure procedures
- Investigating these wake issues will inform other less critical wake situations

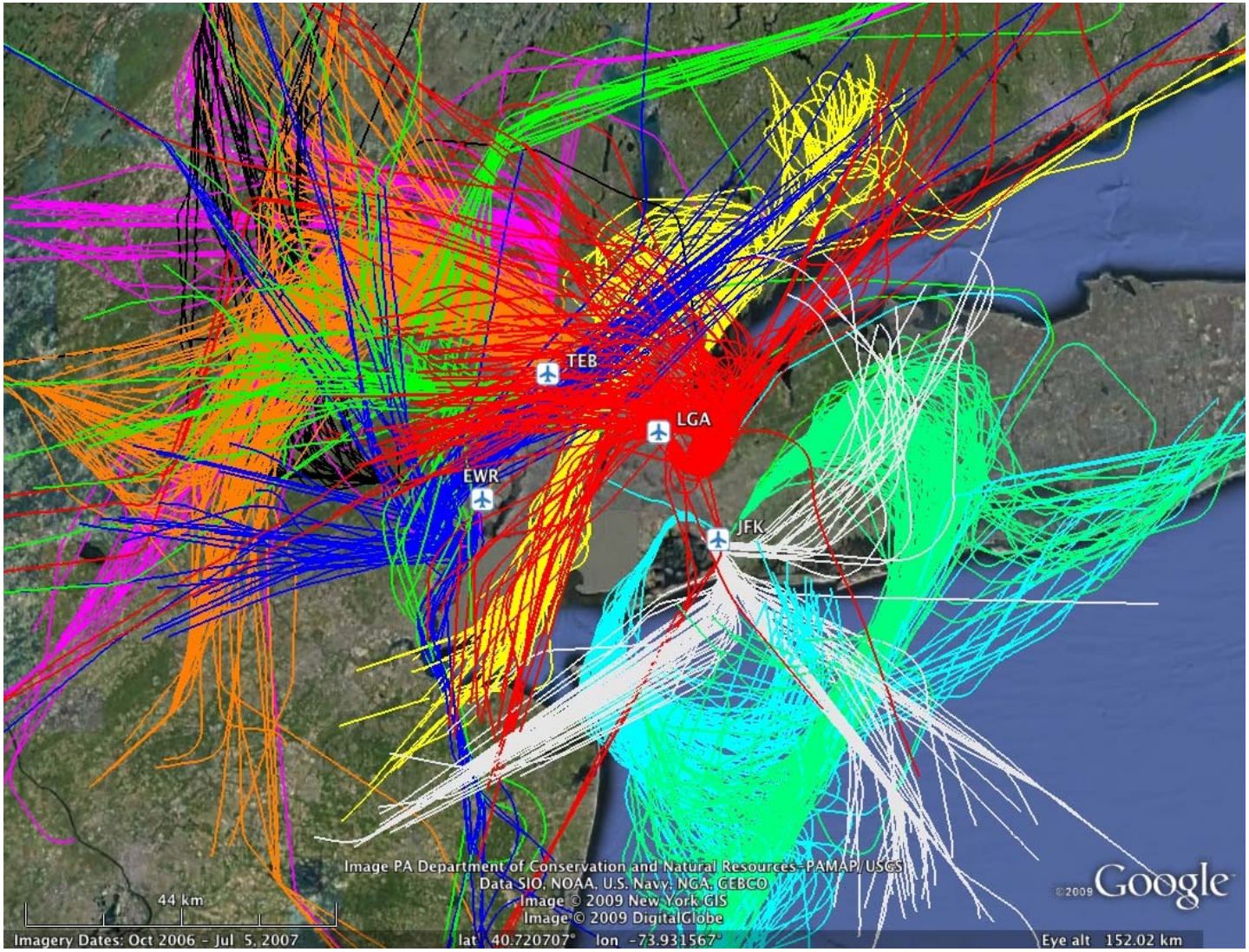


Prototype NextGen Procedures to Evaluate Wake Vortex Issues

- NextGen lacked sufficient definition for in depth analysis, therefore hypothetical prototype NextGen procedures were created to facilitate modeling the wake hazard of potential close proximity procedures
  - Newark (EWR) selected as the location for design of wake vortex test procedures due to its:
    - Closely spaced parallel runways (CSPR)
    - Tight airspace geometry
    - Readily available PDARS flight track data
- The wake impact from these test procedures will be modeled by the other members of the team at George Mason University and Virginia Tech
- PDARS flight track data was used as the baseline for development of hypothetical procedures

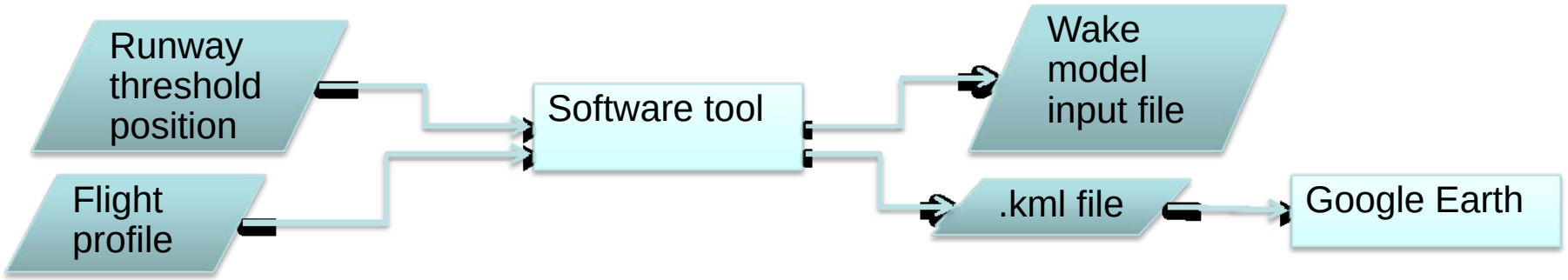
Example New York PDARS Data

EWR 11 Arr.
EWR 22L Arr.
EWR 22R Dep.
JFK 22L Arr.
JFK 13L Arr.
JFK 13R Dep.
LGA 22 Arr.
LGA 13 Dep.
TEB 19 Arr.
TEB 24 Dep.



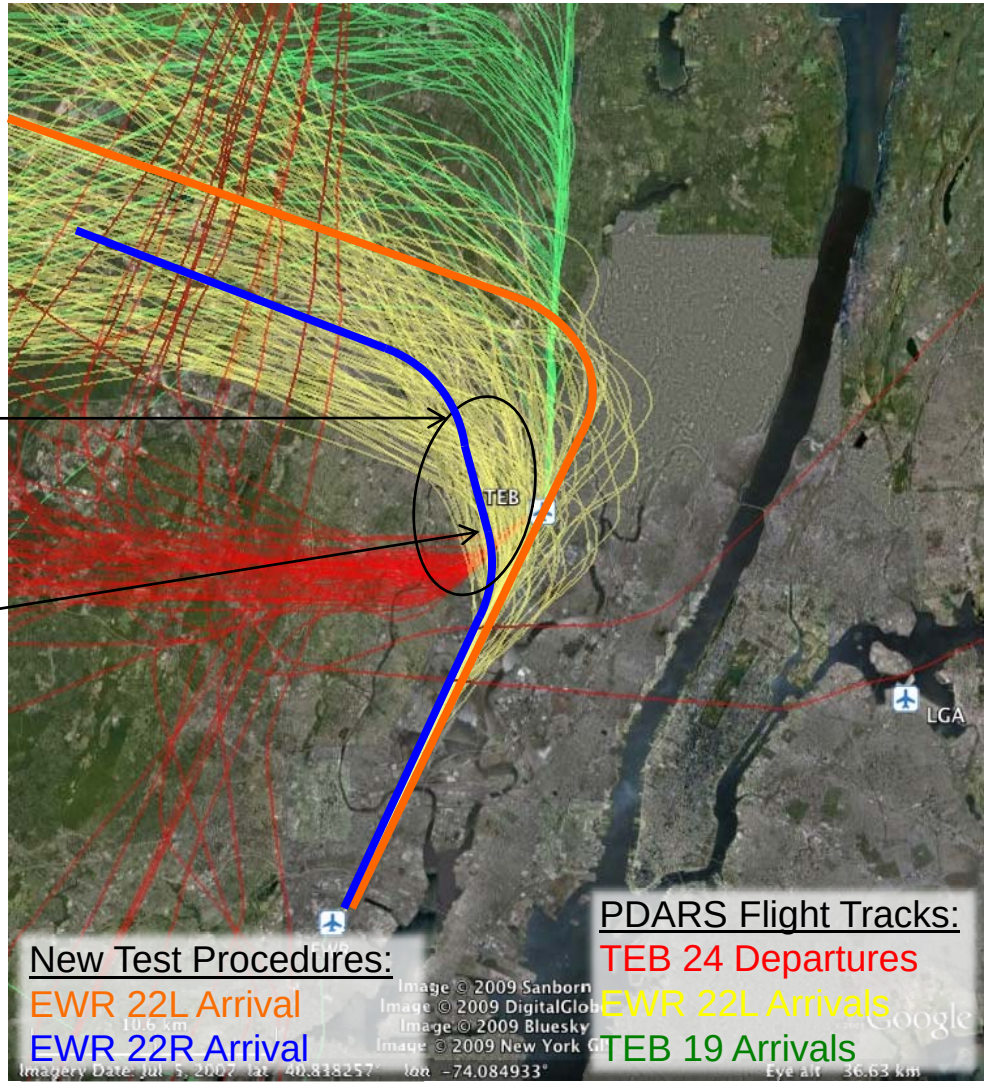
Procedure Generation Tool

- In order to rapidly prototype new procedures a software tool was created
- Flight profile data is input as maneuvers (e.g. straight segment X n.m., turn heading Y radius Z n.m.), allowing intuitive design and adjustment of procedures
- RNP procedure design guidelines and the airport geometry are used to constrain the procedure design
- Output of procedures into Google Earth allows comparison with other data sets such as PDARS flight tracks

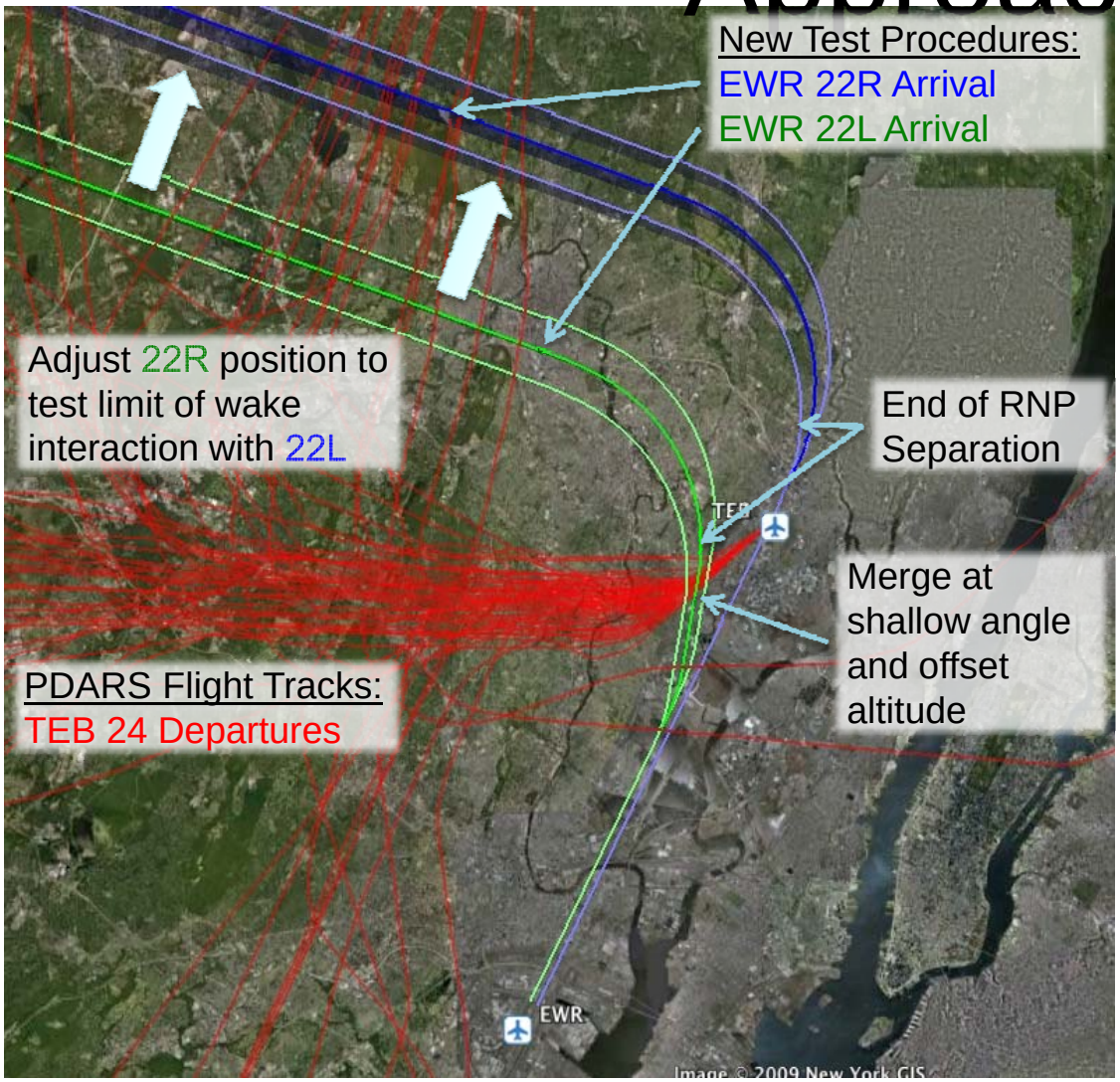


Arrival-Arrival Interaction

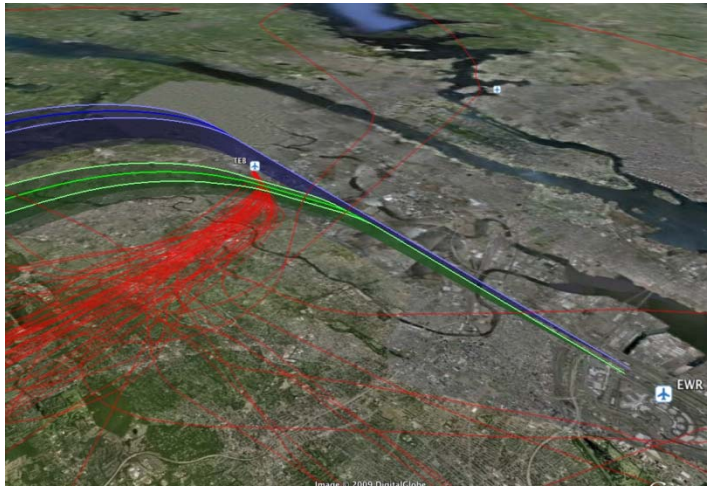
- An example to explore NextGen wake vortex issues on closely spaced turn to final
- Use current 22L maneuvering space for new 22R turn & merge
- Vary EWR 22R turn and final approach geometry to test the limit of wake interaction with EWR 22L during the merge maneuver



Potential NextGen EWR 22 Approach

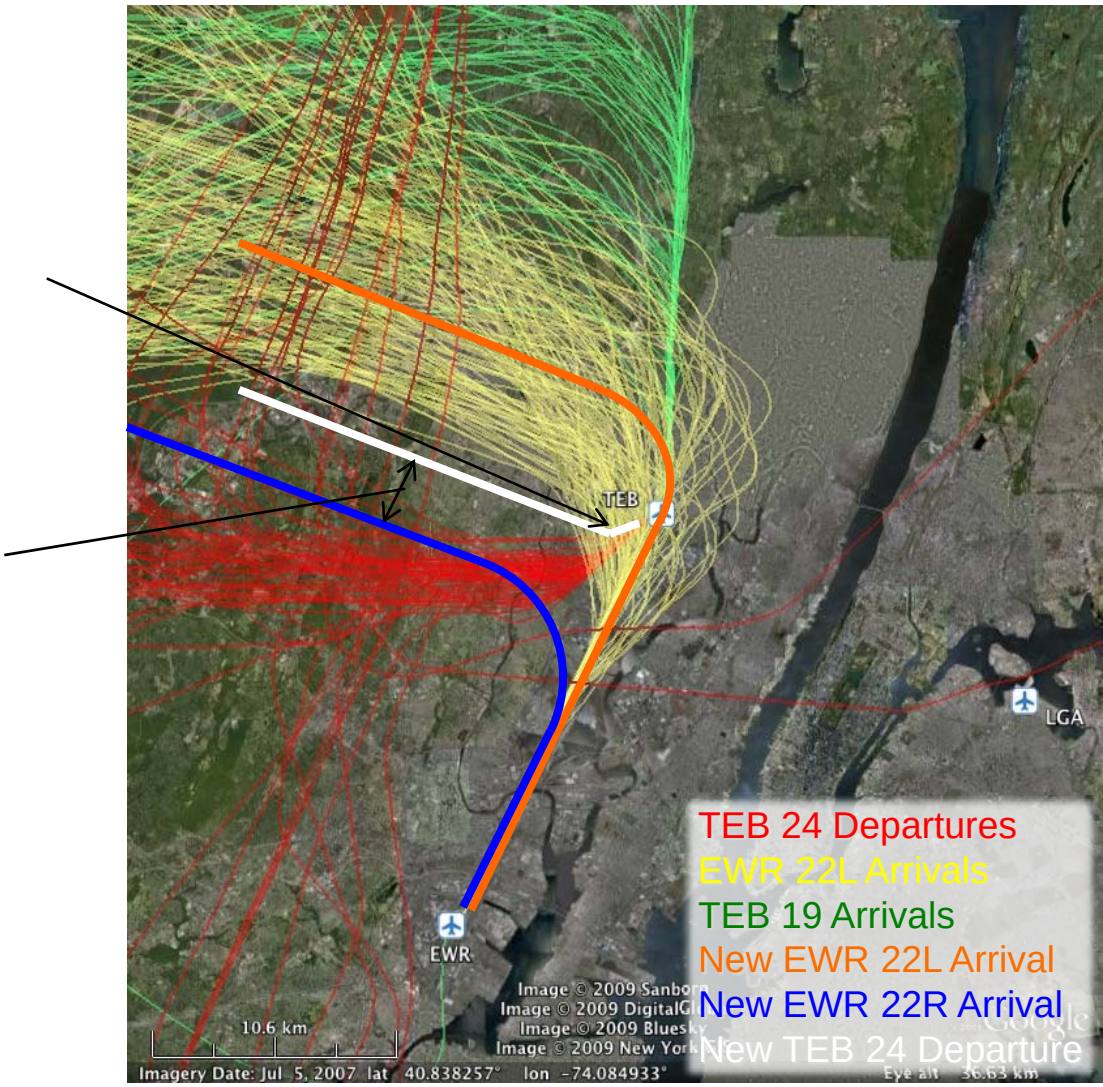


- Assume tight RNP (0.3 shown) is available
- Use current 22L maneuvering space for new 22R turn & merge
- Vary geometry to test the limit of wake issues at several interaction points

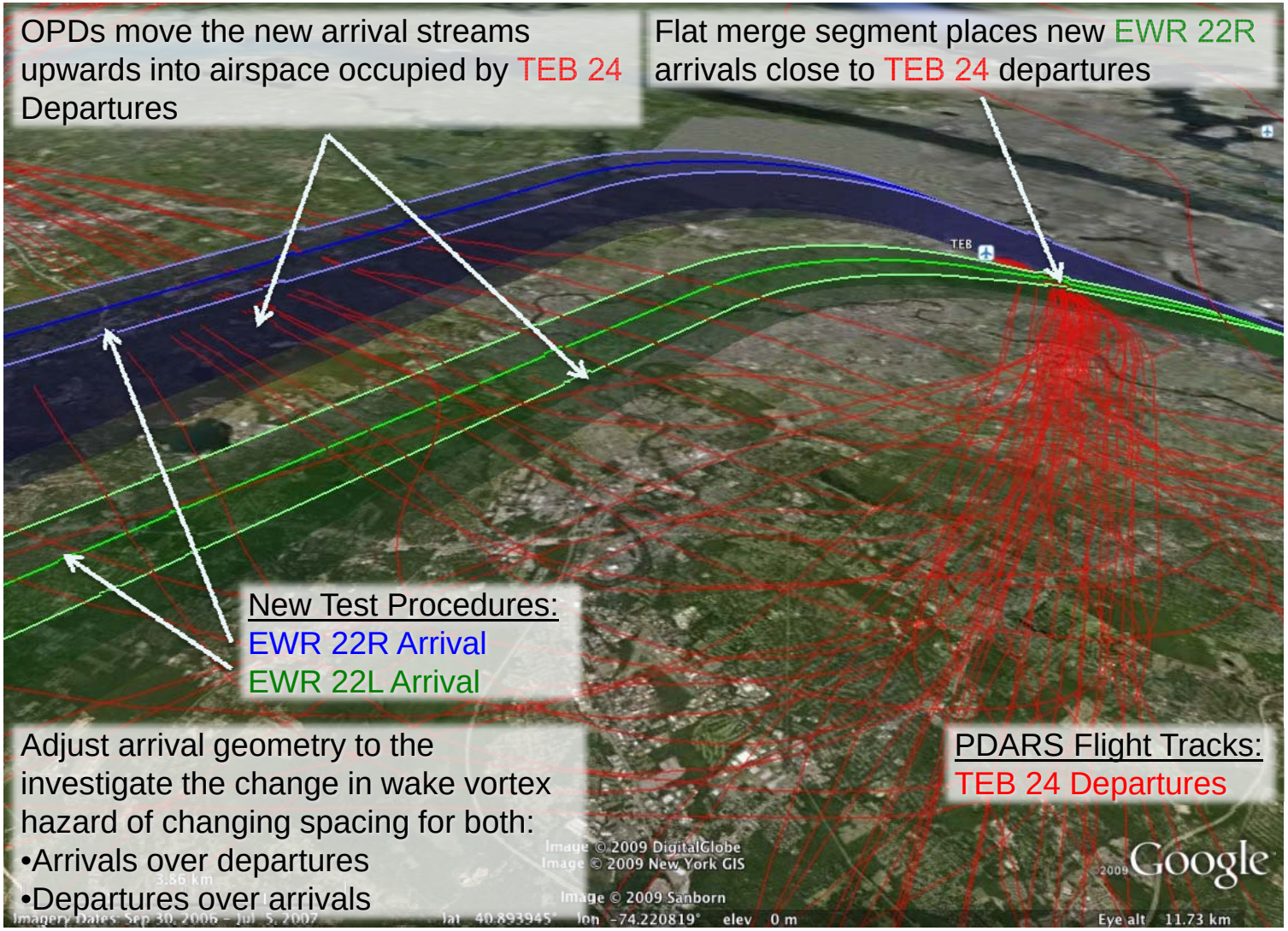


Arrival-Departure Interaction

- Depart TEB 24 between EWR 22 L and R arrival streams
- Test the limits placed on the TEB 24 departure climb by the EWR 22L arrivals
- Also explore the interaction between parallel approach and departure routes

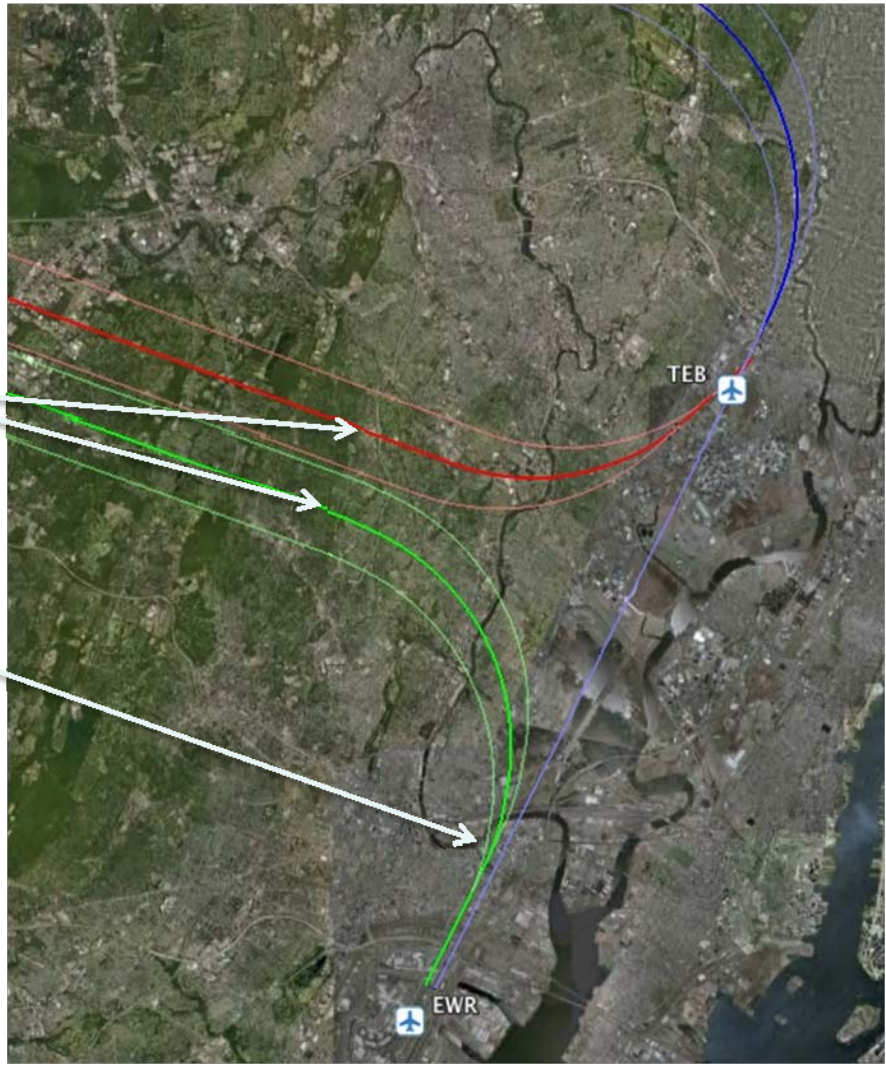


Arrival Departure Interaction



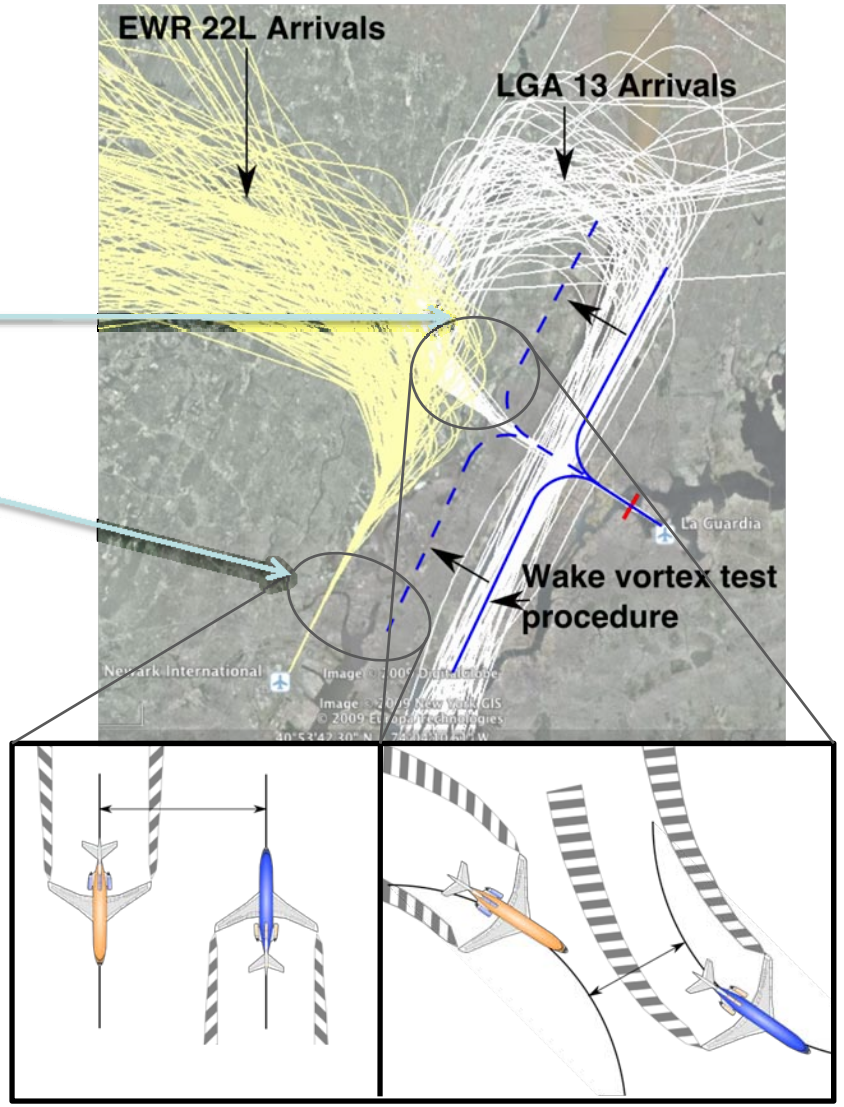
Alternate Interaction Geometry

- An alternative solution would be to place TEB 24 departures between the two EWR 22 arrival streams
- This allows the investigation of parallel opposite direction arrival-departure interactions
- This design may not provide enough time to perform the merge procedure



Arrival-Arrival Interaction

- Precision navigation may permit unusual interaction geometries in NextGen, such as:
  - Simultaneously maneuvering arrivals
  - Parallel opposite direction arrival flows
- Test the wake vortex hazard for different lengths of final approach into LGA



LGA-EWR Arrival-Arrival Interaction

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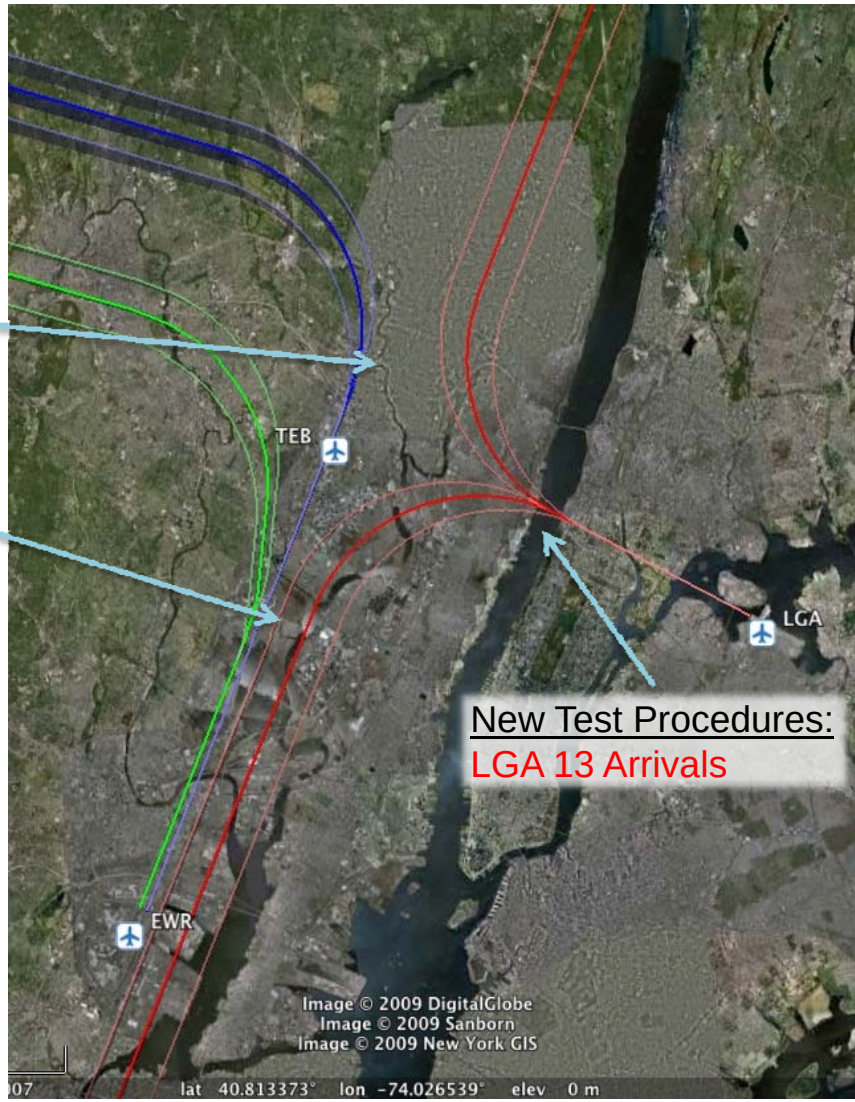
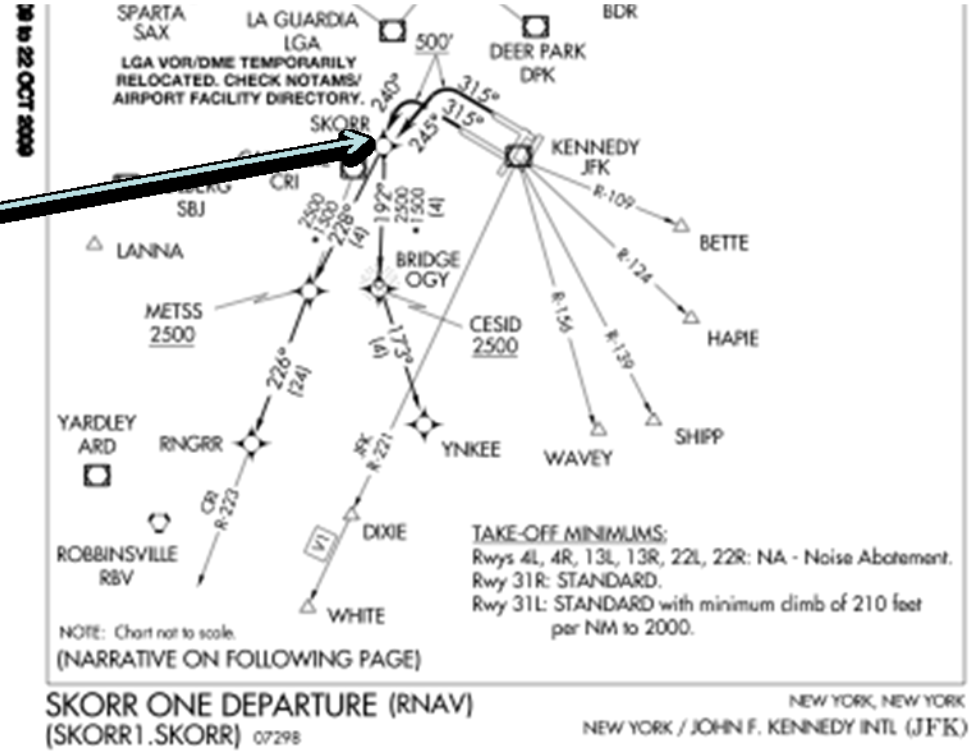
  - Simultaneously maneuvering arrivals
  - Parallel opposite direction arrival flows
- Test the wake vortex hazard for different lengths of final approach into LGA



Departure-Departure Interaction

- JFK SKORR ONE departure currently departs aircraft from adjacent parallels to the same fix (SKORR)
- Current operations safely separate these departures
- Modeling reduced separation between successive departures will explore the separation limits between tight proximity departure routes



http://www.naco.faa.gov/d-tpp/0910/00610SKORR.PDF

Questions?