Incidents and Statistics: The Need for Improved Means to Quantify Safety

3rd WakeNet2 Europe Workshop

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Acknowledgments

- Wayne Bryant, WakeVAS program manager NASA

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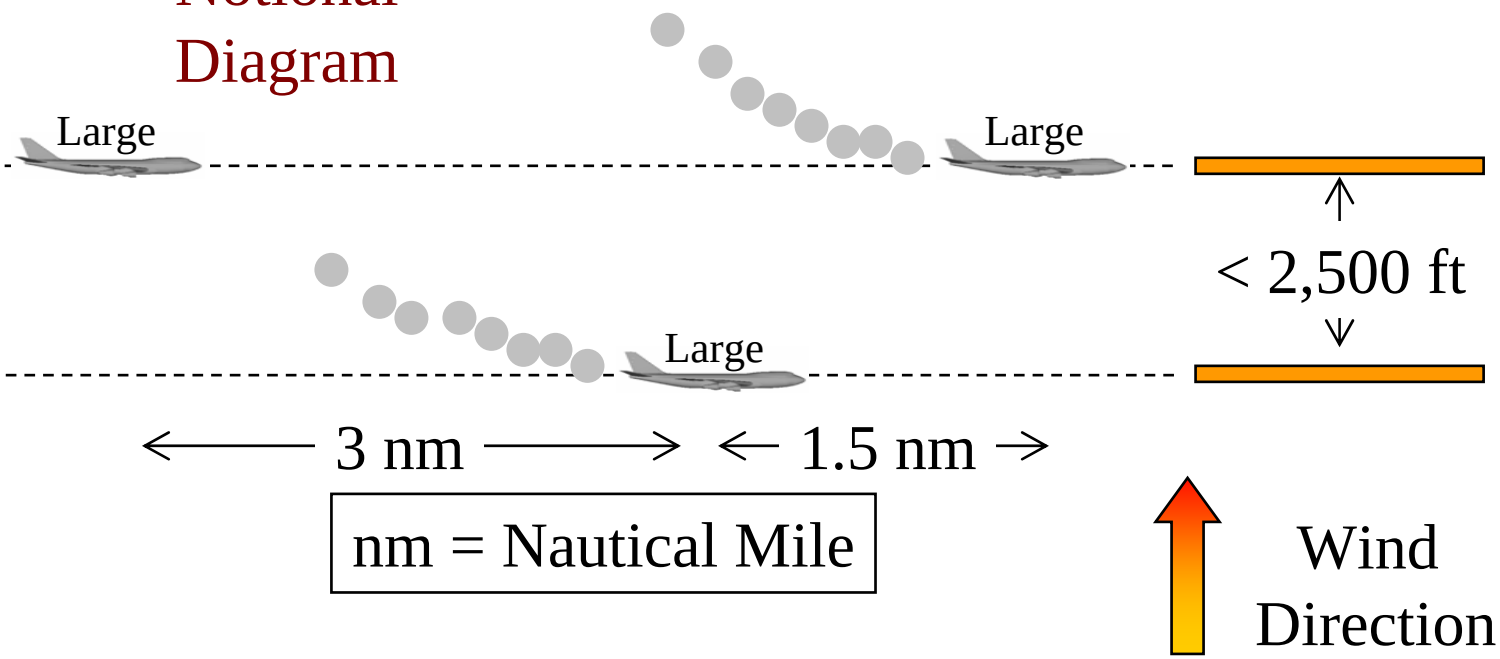
Example System for Analysis

Reduced Separation Conops

Notional Diagram



Under sufficient cross-wind, wake separation of aircraft on upwind path can be reduced

Lang, S., A. Mundra, W. Cooper, B. Levy, C. Lunsford, A. Smitt, J. Tittsworth, 2003, "A Phased Approach to Increase Airport Capacity Through Safe Reduction of Existing Wake Turbulence Constraints," *Air Traffic Control Quarterly*, **11**(4), 331-356.

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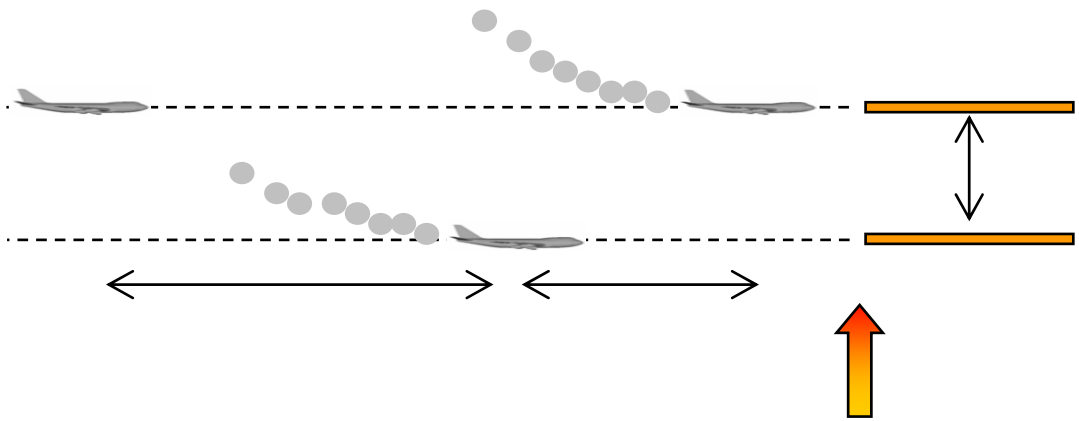
Need for Quantitative Methods

- What degree of accuracy is required in the wind sensors?
- What duration of prediction time is required?
- How many wind sensors are needed?
- What level of reliability is needed for the wind sensors?
- How close can parallel runways be to safely implement the proposed procedures?
- Does the system meet ICAO safety standards?



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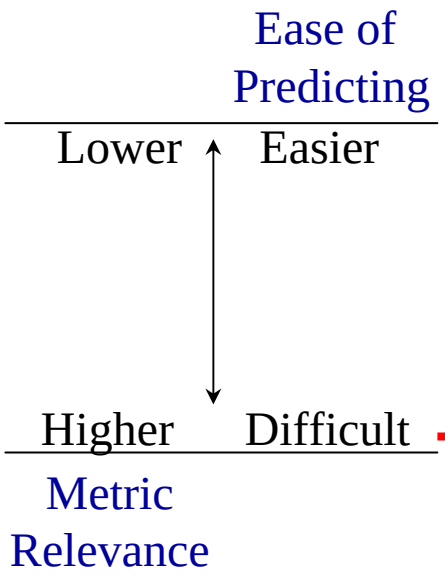
Some Safety Metrics



- **Airplane inter-arrival time**
- **Prob (simultaneous runway occ.)**
- **Prob (wake vortex encounter)**

"Incident" Metrics

- **Prob (collision), Prob (vortex accident)**

Incident related metrics give an *indication* of safety but not a *proof* of safety

- Wells, A. T., 2001. *Commercial Aviation Safety*, 3rd ed.
- Hayne, R. C., 2002. Ph.D. Dissertation.
- Xie, Y., 2005. Ph.D. Dissertation.

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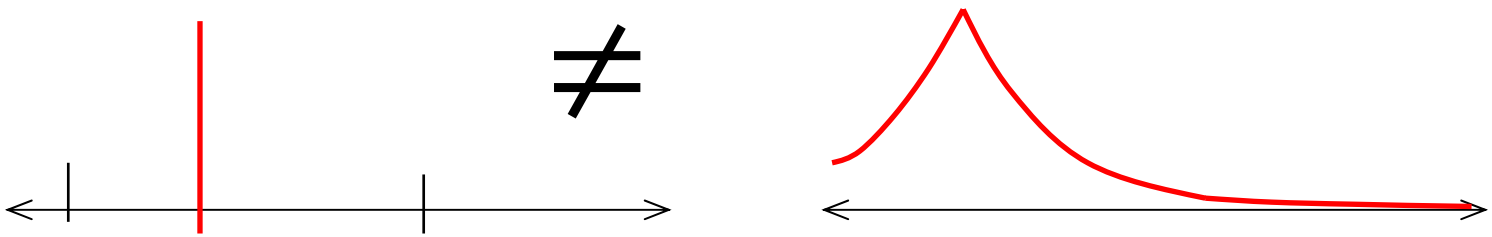
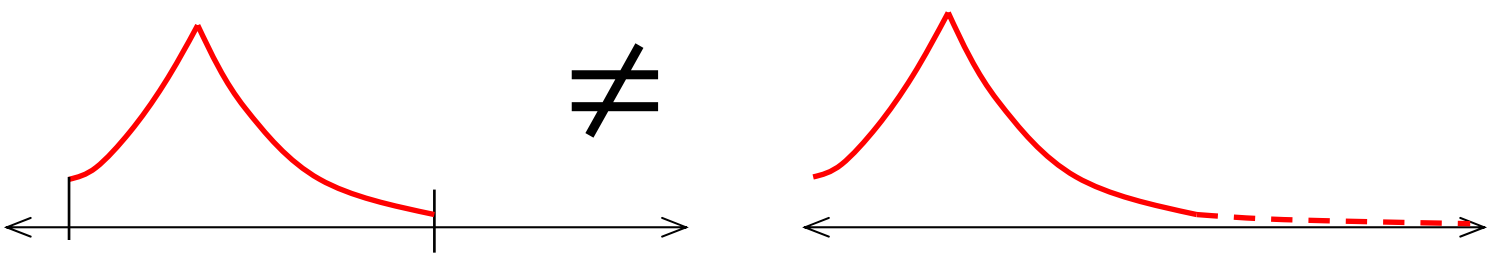
Some Issues in Quantitative Modeling

- The probability distribution matters
  - But, hard to “think probabilistically”



- The tail of the distribution matters
  - But, cannot extrapolate tail beyond what is observed



Outline

- Probabilistic calculation of wake vortex encounters
  - Visualization
- Data requirements for quantitative analysis

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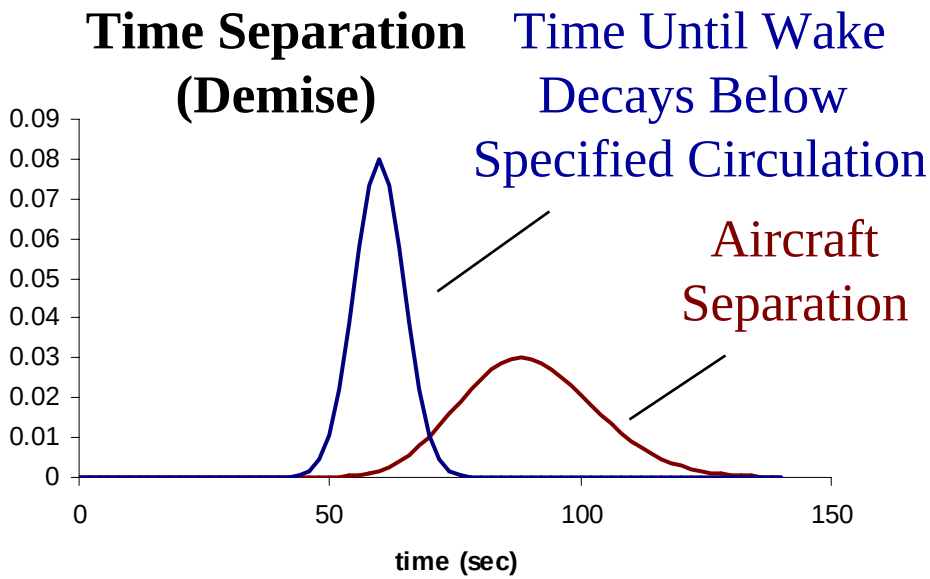
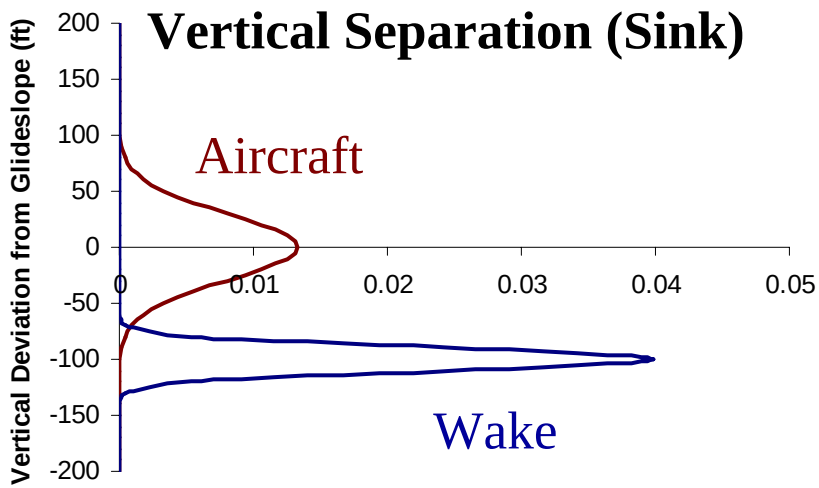
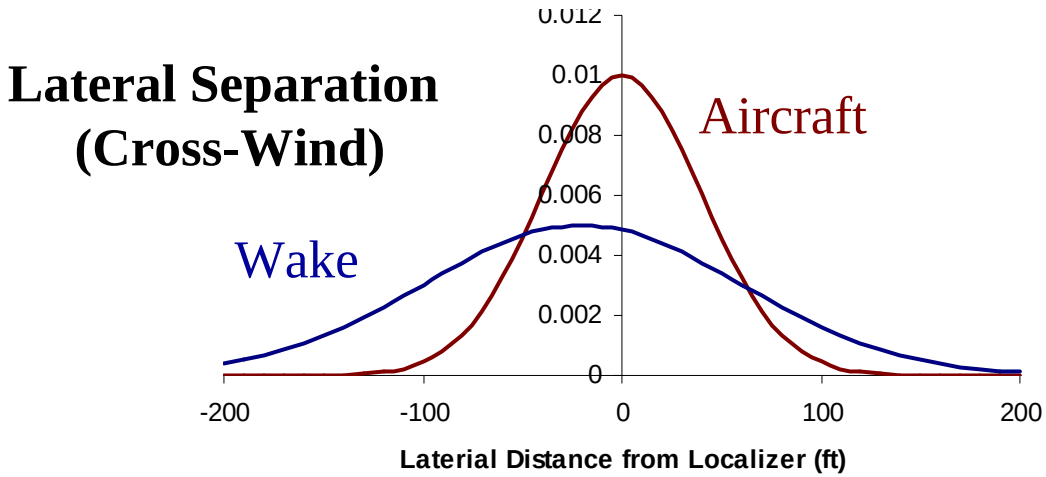
3 Dimensions of an Encounter







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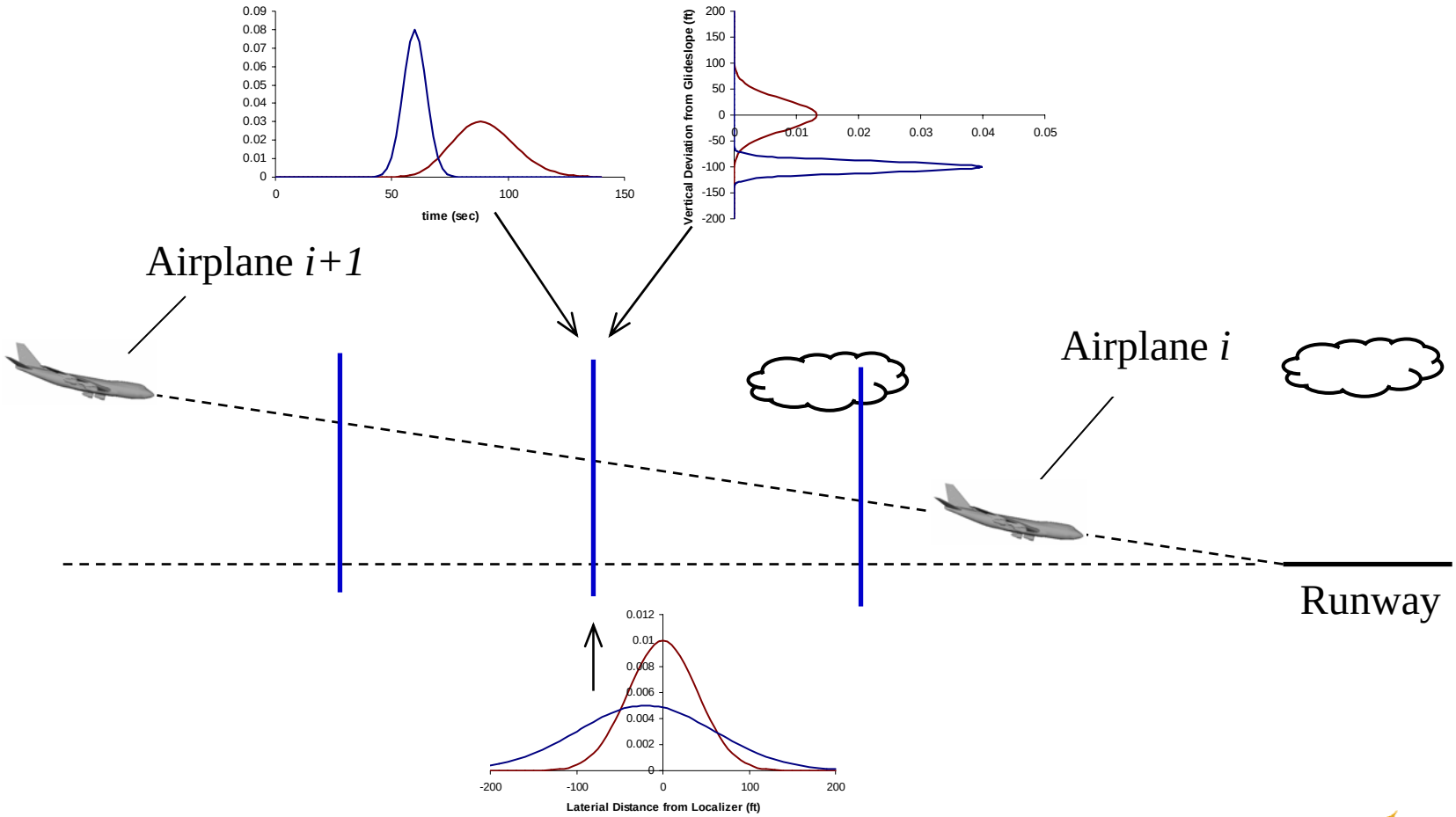
Variation Along Approach Path



Distributions vary depending on distance from runway

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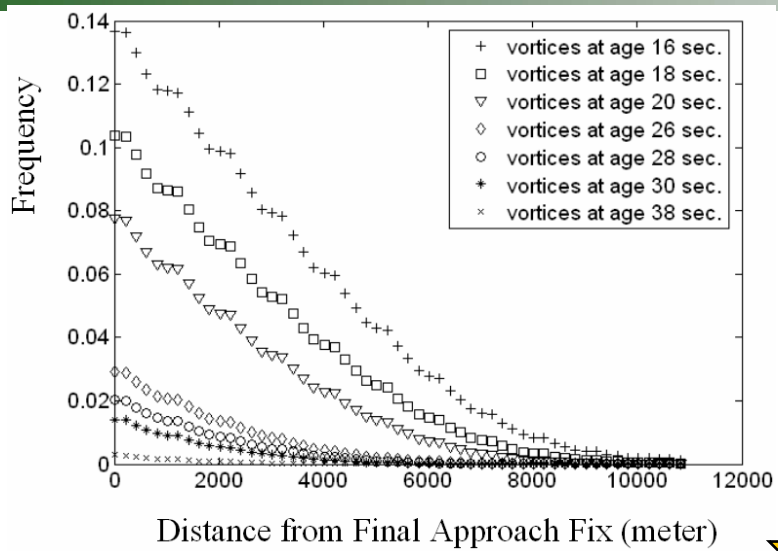
Visualization Demonstration

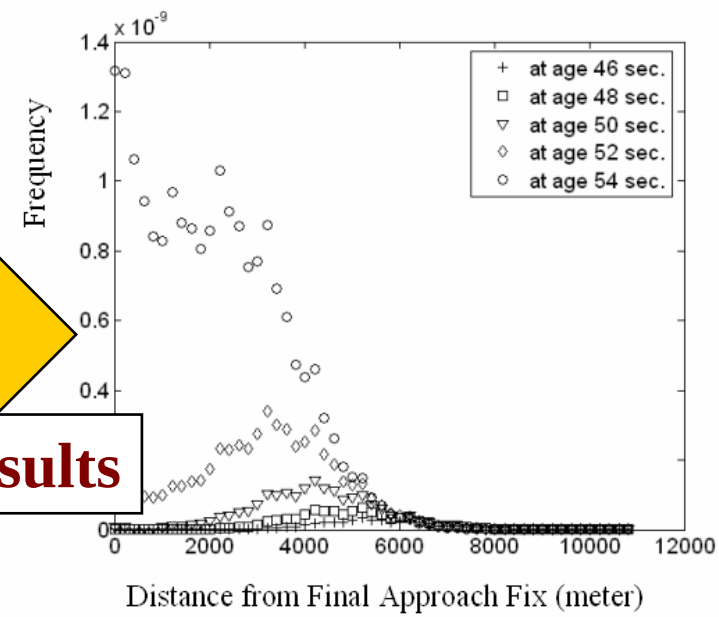
Conservative Probabilistic Model



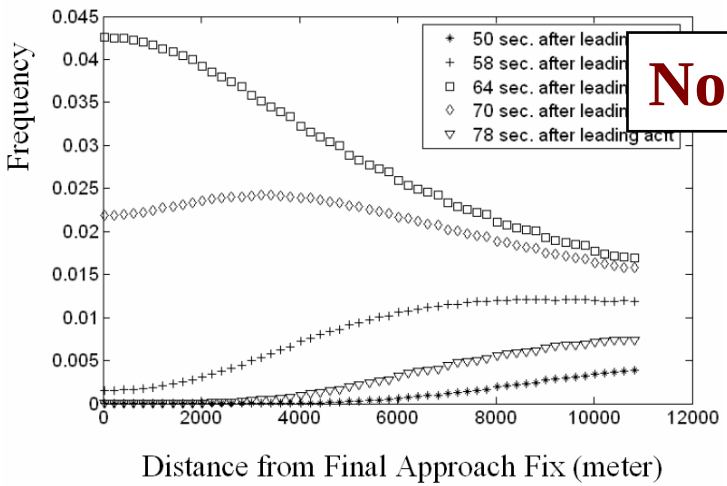
Conditional Probability of Vortex Encounter

Xie, Y., Shortle, J., Choroba, P, 2005. "Quantitative Estimation of Wake Vortex Safety Using the P2P Model," *6th USA/Europe ATM R&D Seminar*.

Notional Results



Probability of Vortex Encounter



Probability of Aircraft Passing A Location at Different Time

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Data Requirements

Key Questions

- How much data are needed to do quantitative safety analysis?
- Can we really estimate a 10^{-9} event?

Outline

- Reich Collision Model
- Extension to wakes

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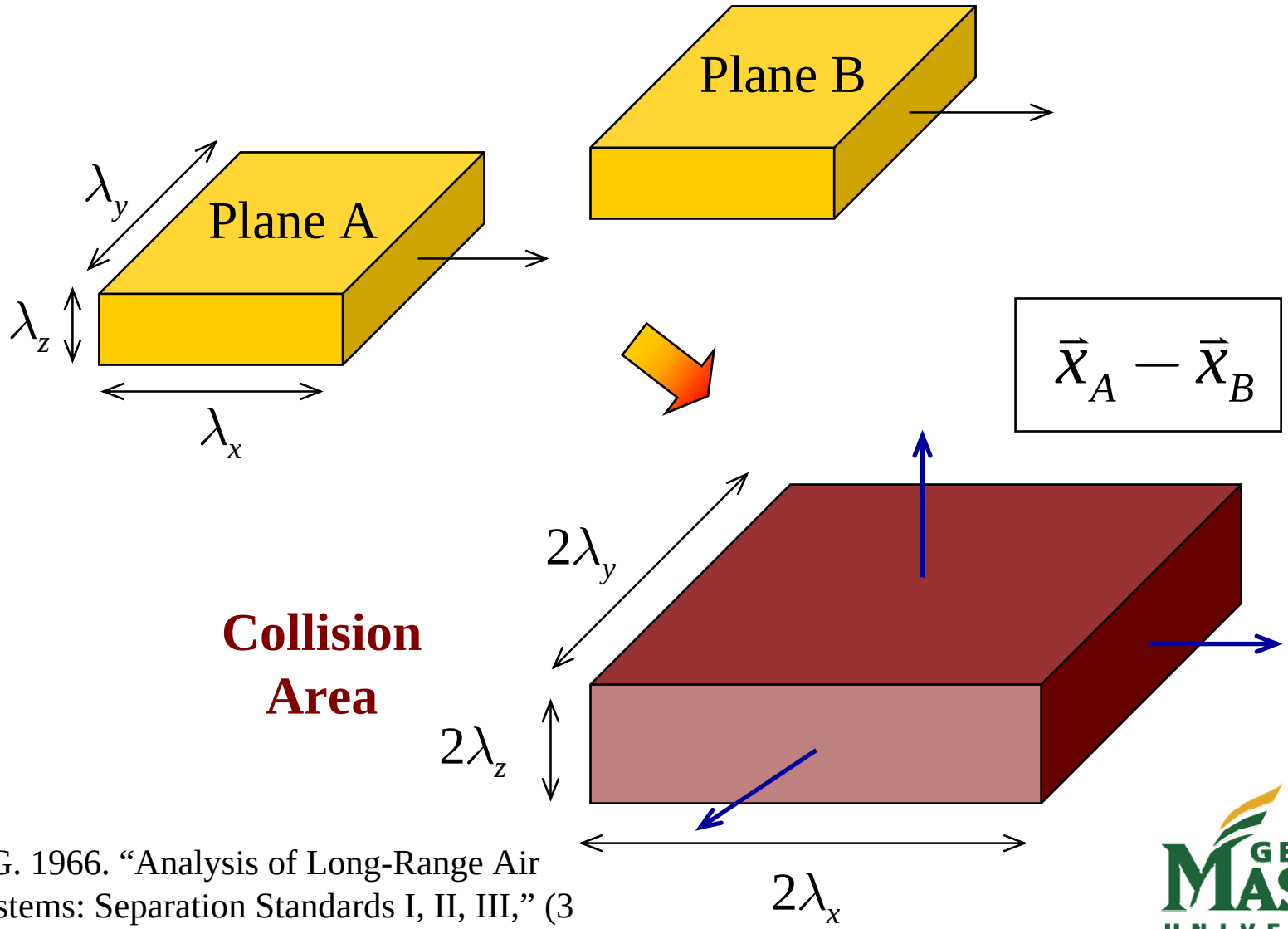
Reich Collision Model



Reich, P. G. 1966. "Analysis of Long-Range Air Traffic Systems: Separation Standards I, II, III," (3 papers) *J. of Navigation* **19**.

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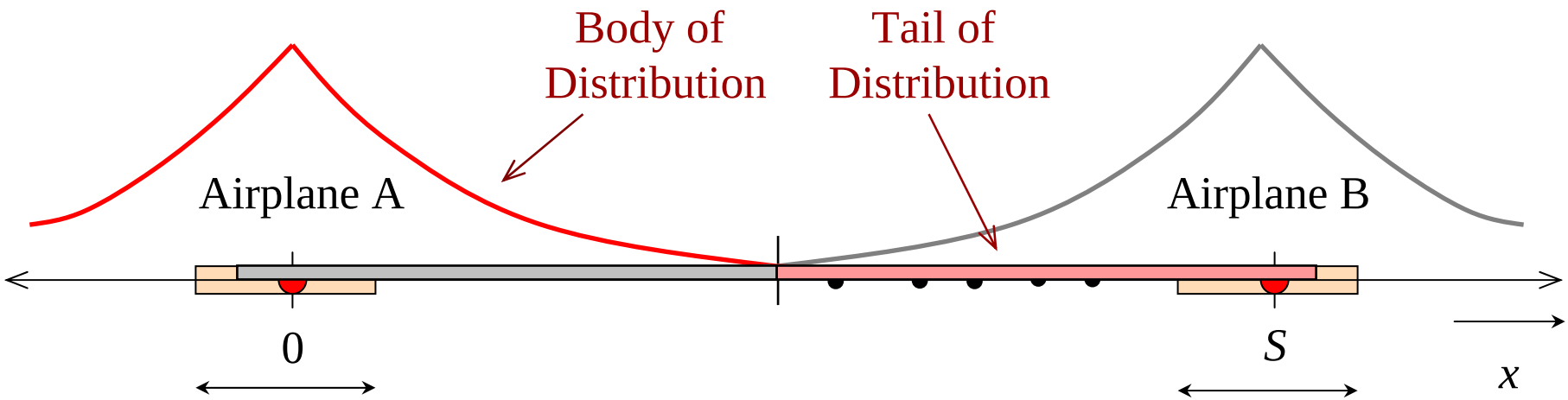
Overlap Probability Calculation



- Count number of observations in tail. 5
- Estimate upper bound on tail probability via Poisson confidence interval 11.7 / 10,000
- Choose the form of the tail shape Uniform
- Based on upper bound for tail probability, compute overlap probability

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Data Requirements

Basic Question: How much data are needed for a good estimate of the overlap probability?

1. Let p^* be the true overlap probability
2. Let c be a confidence level (e.g., $c = 0.99$)
3. Let P be the conservative estimate for the overlap probability, based on making N observations.

$$P(p^* < P) = (1+c)/2$$

4. Determine k such that:

$$P(p^* < P < k \cdot p^*) = c$$

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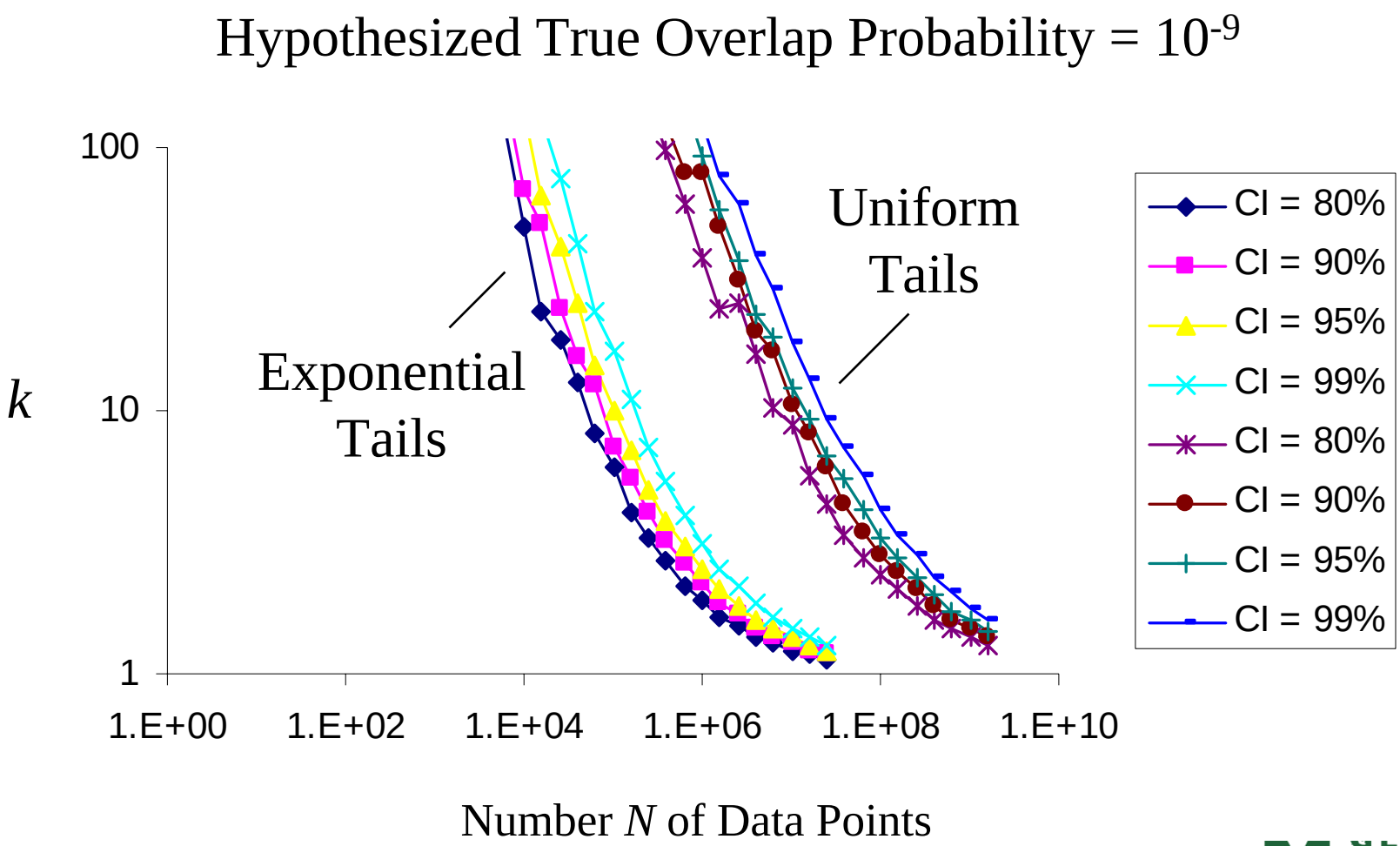
Data Requirements



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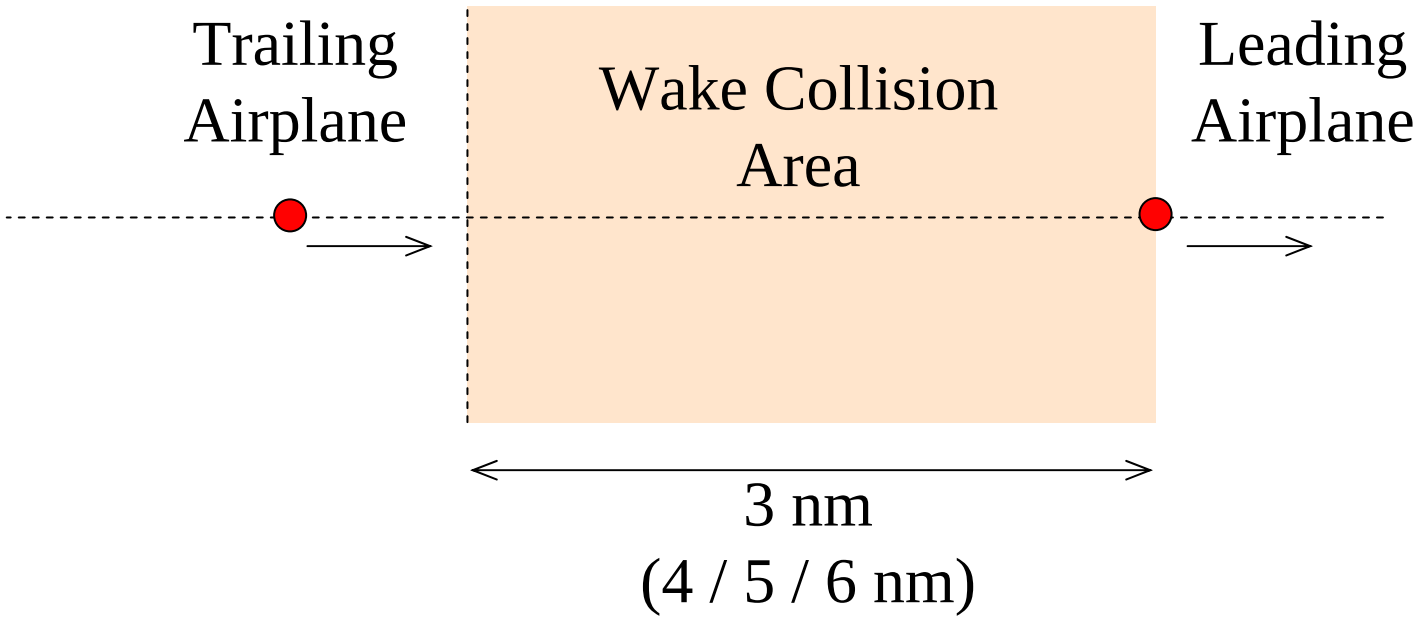
Current Assumptions



Physics included:

- *Conservative* estimate of wake demise

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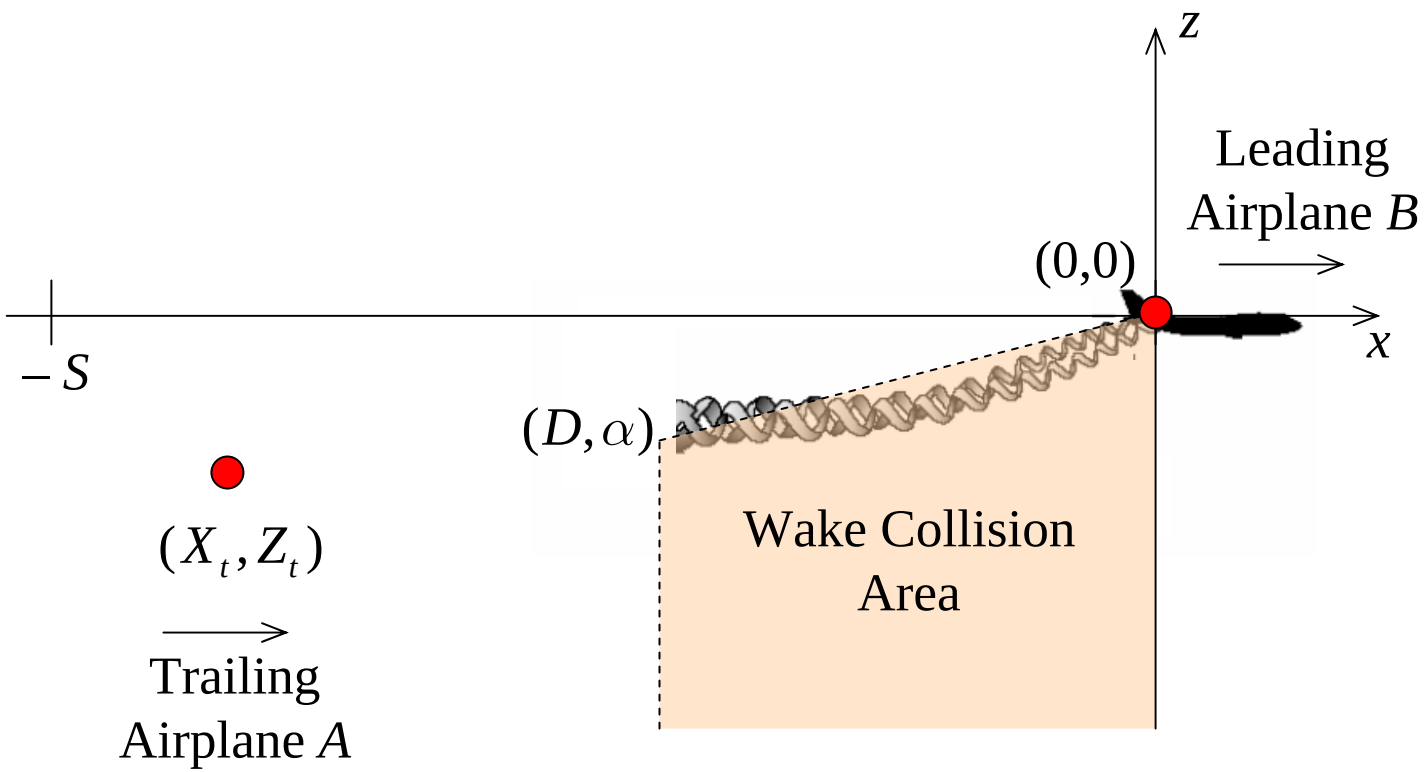
Extension of Reich Model to Wakes



Physics included:

- Probabilistic estimate of wake demise
- Wake sink

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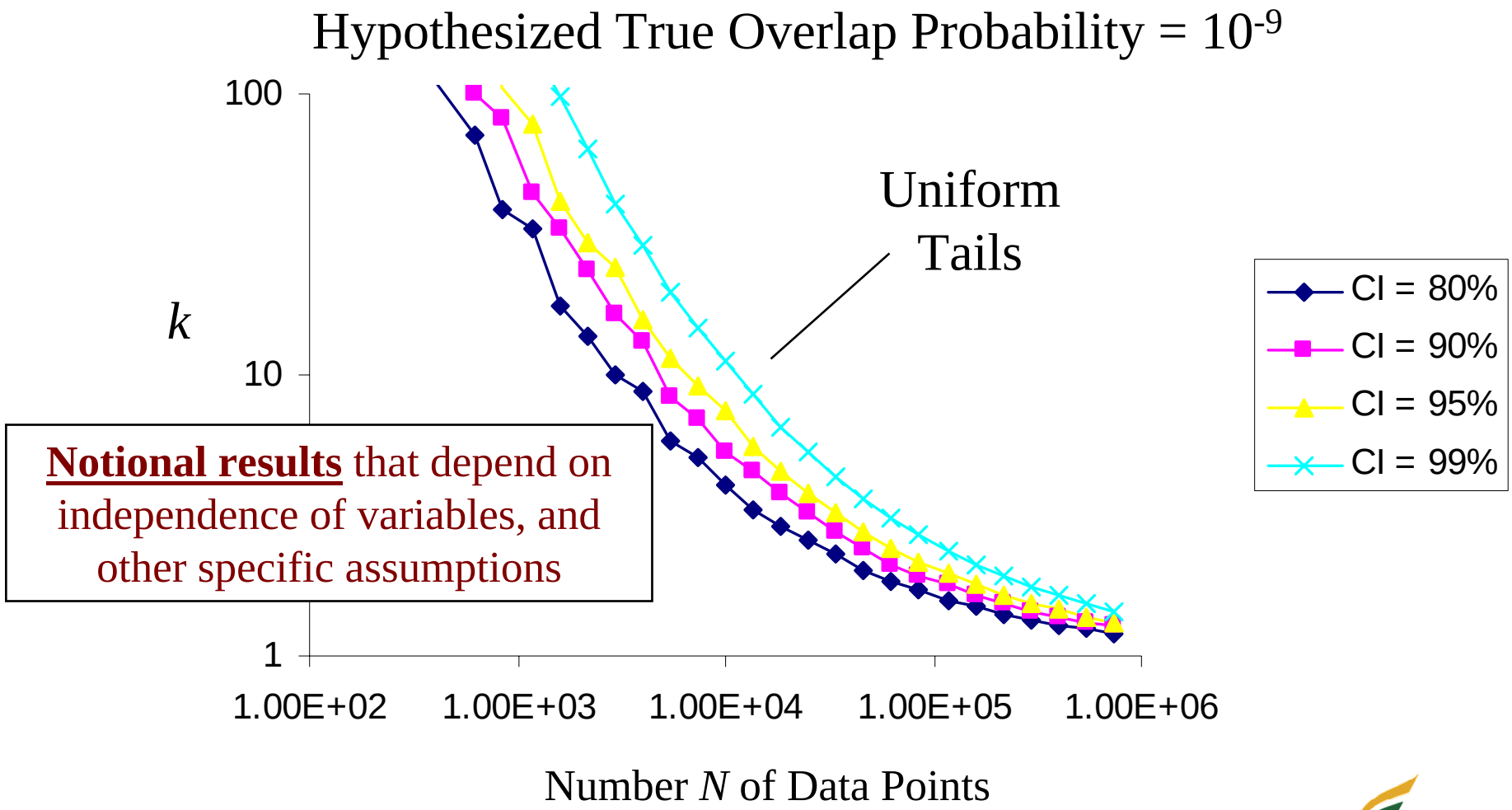
Data Requirements



Notional results that depend on independence of variables, and other specific assumptions

Data requirements less if trying to predict less-rare event (10^{-6})

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Summary

- Quantitative methods are needed for many analyses
  - Natural variation of process. No “initiating hazard.”
- Visualization of probabilistic effects
- The tails of the distributions matter
  - Knowing the body of the distribution does not imply knowing the tail
  - High level of incidents does not necessarily mean high level of accidents
  - Extrapolation from incidents to accidents should be justified statistically
- Data requirements for severe wake encounters may be achievable
  - Larger number of contributory “semi-rare” events

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Questions?

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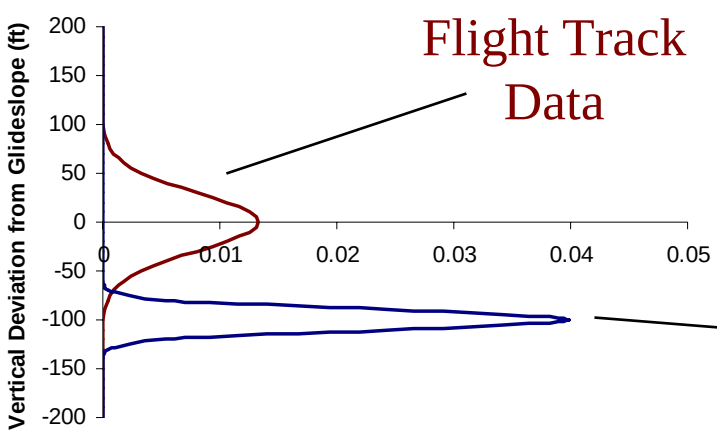
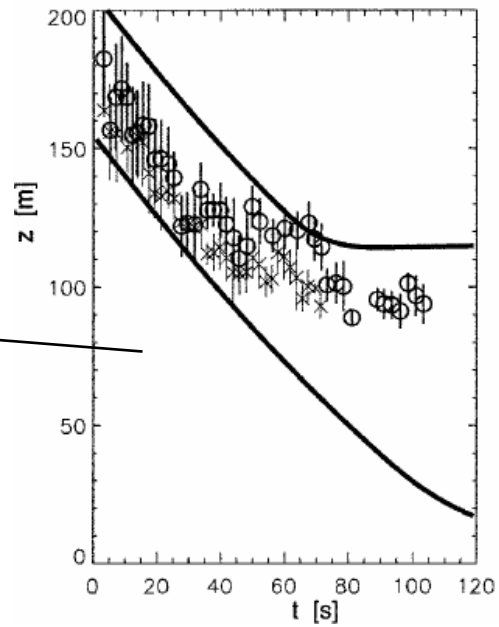
Modeling of Probability Functions



Flight Track Data

Wake Model or Data



Sample Output of P2P Wake Model

Holzapfel, F. 2003. "Probabilistic Two-Phase Wake Vortex Decay and Transport Model," *Journal of Aircraft* **40**, 323 - 331.

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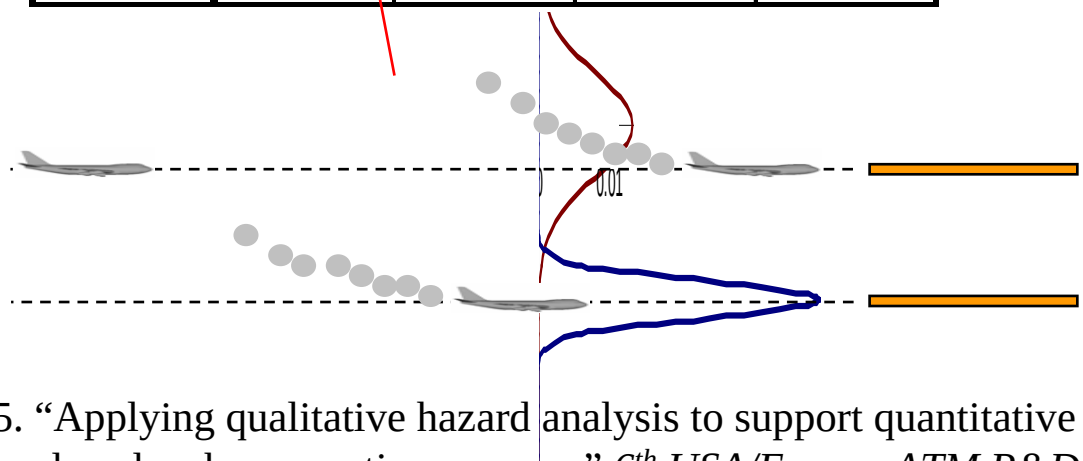
Sample Hazard Analysis

Modeling Difficulty

Lower ⟷ Higher

Risk	i	ii	iii	iv
Higher ↑				
1-B	1	1	4	5
1-C	1	4	9	6
↓ Lower				
1-D	3	2	4	3



Shortle, J., Allocco, M, 2005. "Applying qualitative hazard analysis to support quantitative safety analysis for proposed reduced wake separation conops ," *6th USA/Europe ATM R&D Seminar*.

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