Safety – The Air Passenger Experience

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Disclaimer

- The views in this presentation are *my own*. I am not representing the FAA, DOT, NASA, etc.

Aviation: Are We There?

- "Fatal accidents in the first world are on the verge of extinction. ... But a near extinct species can stage a major comeback." (Barnett 2008).
- Some questions:
  - Is a zero-fatality goal possible?
  - How close are we?
  - How will we know when the goal is reached?
  - Going forward: Safety-capacity trade-offs

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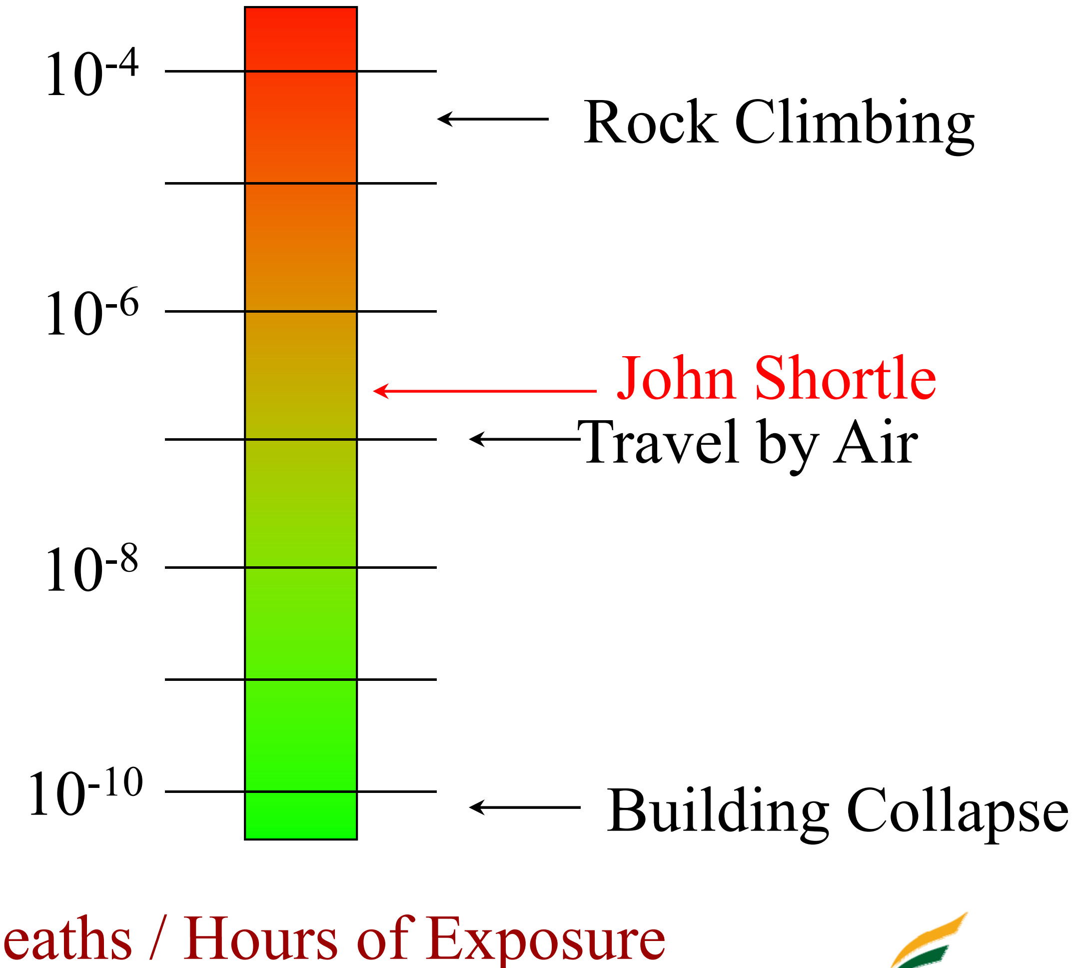
Barnett, A. 2008. Is it really safe to fly? *Tutorials in Operations Research*, 17-30.

Levels of Risk

<u>Sources</u>

- *Risk: Analysis, Perception, and Management.* Report of a Royal Society Study Group, London 1992.
- National Vital Statistics Reports, Vol. 52, No. 3, www.cdc.gov/nchs/about/major/dvs/mortdata.htm, 2003.
- http://www.ntsb/gov/aviation/Stats.htm, Part 121, 1986-2005, assumes every passenger flies on an average-length flight of about 1.6 hours.



Aviation Metrics

<u>U.S. Part 121, 1986 – 2005</u>

• Fatal accidents per flight hour	2.6×10^{-7}
• Fatal accidents per mile flown	6.3×10^{-10}
• Fatal accidents per departure	4.0×10^{-7}
• Passenger fatalities per departure	1.1×10^{-5}
• Passenger fatalities per enplanement	1.9×10^{-7}

1. Fatal accidents includes non-passenger fatalities
2. Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under 14 CFR 121.
3. Fatal accident rates do not include illegal acts (e.g., terrorism). However, passenger fatality rates do include illegal acts, but they exclude crew deaths
4. Accident statistics are averages of yearly averages, passenger fatalities are averages across 1986-2005.

Source: http://www.ntsb.gov/aviation/Stats.htm

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Some Problems with Metrics

Fatal accidents per flight hour

A crash in which 1 out of 100 people killed
equally serious as
A crash in which 100 out of 100 people killed

$$\frac{\text{Total \# of flights with at least one fatality}}{\text{Total \# of flight hours}}$$

Crashes on long flights less serious
than crashes on short flights

Barnett, A. 2008. Is it really safe to fly? *Tutorials in Operations Research*, 17-30.

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A "Passenger" Metric (Barnett 2008)

- What is the probability that I am killed on a flight?
  - I randomly choose a flight
  - I randomly pick a seat on the flight
  - What is probability that I am killed?

$$\sum_{i=1}^{N} \frac{k_i / n_i}{N}$$

Number of passengers killed on flight *i*

Number of passengers on flight *i*

Total number of flights

Barnett, A. 2008. Is it really safe to fly? *Tutorials in Operations Research*, 17-30.

A "Passenger" Metric

- Taking one flight per day, it would take (on average) 55,000 years to be killed in a flight.
- Metric based on:
  - Scheduled flights between two airports in the first world
  - Data period covers 2000-2007

Barnett, A. 2008. Is it really safe to fly? *Tutorials in Operations Research*, 17-30.

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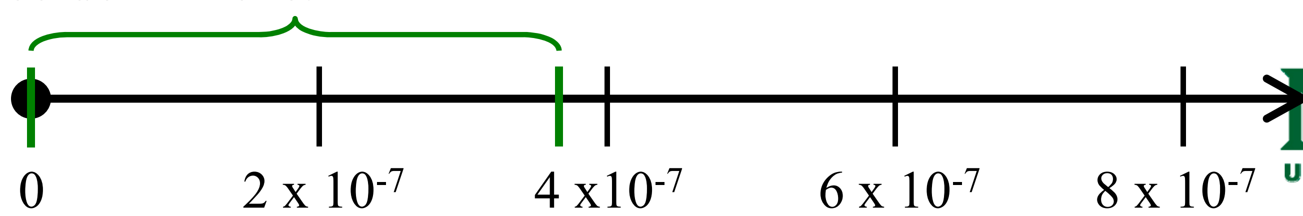
Statistics of Rare Events

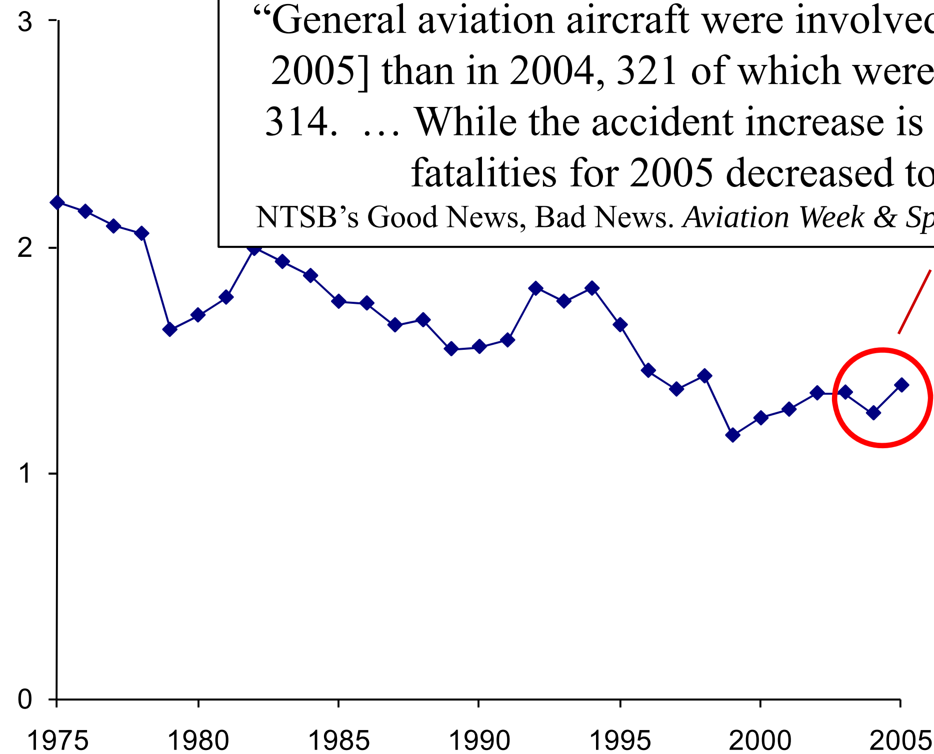
- Suppose there are *zero* fatal accidents in 2011. What can we conclude?
  - The fatal accident rate in 2011 *was* zero.
  - But, how do you feel boarding a flight on January 1, 2012?
- If you assume:
  - The number of fatal accidents in a year is a *Poisson* random variable
  - 2011 and 2012 are statistically identical (and independent)
- Then you can conclude:
  - A 95% confidence interval for the "true" unknown average number of accidents per year is between 0 and about 3.7.
  - Or, assuming 10^7 flights per year, the confidence interval for the fatal accident rate is:



General Aviation

Fatal Accidents per 100,000 (10^5) Flight Hours:

General Aviation



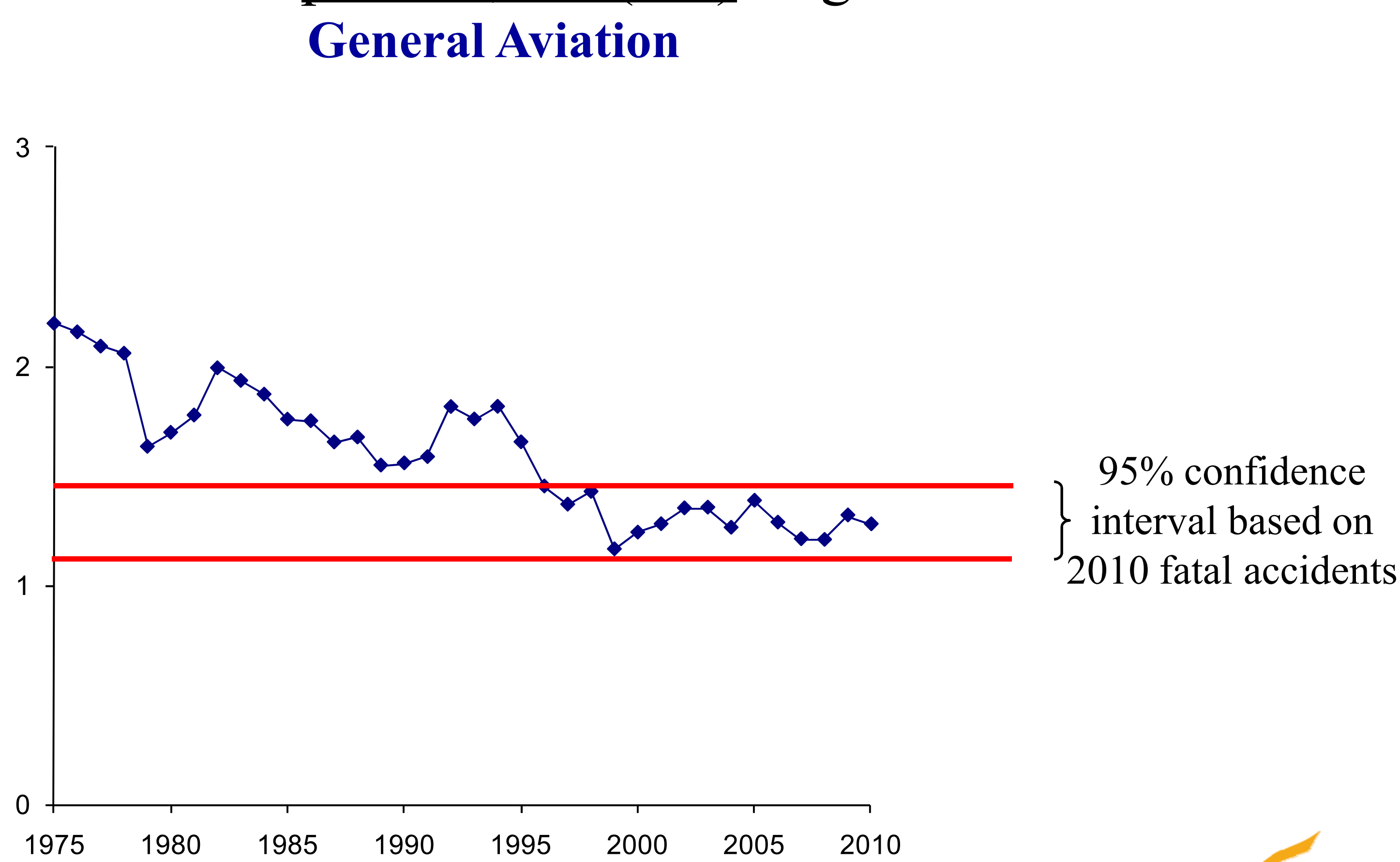
"General aviation aircraft were involved in 52 more accidents [in 2005] than in 2004, 321 of which were fatal – an increase from 314. … While the accident increase is "disappointing," … total fatalities for 2005 decreased to 600 from 636."

NTSB's Good News, Bad News. *Aviation Week & Space Technology*, March 27, 2006.

Data source: http://www.ntsb.gov/aviation/Stats.htm

General Aviation

Fatal Accidents per 100,000 (10^5) Flight Hours:

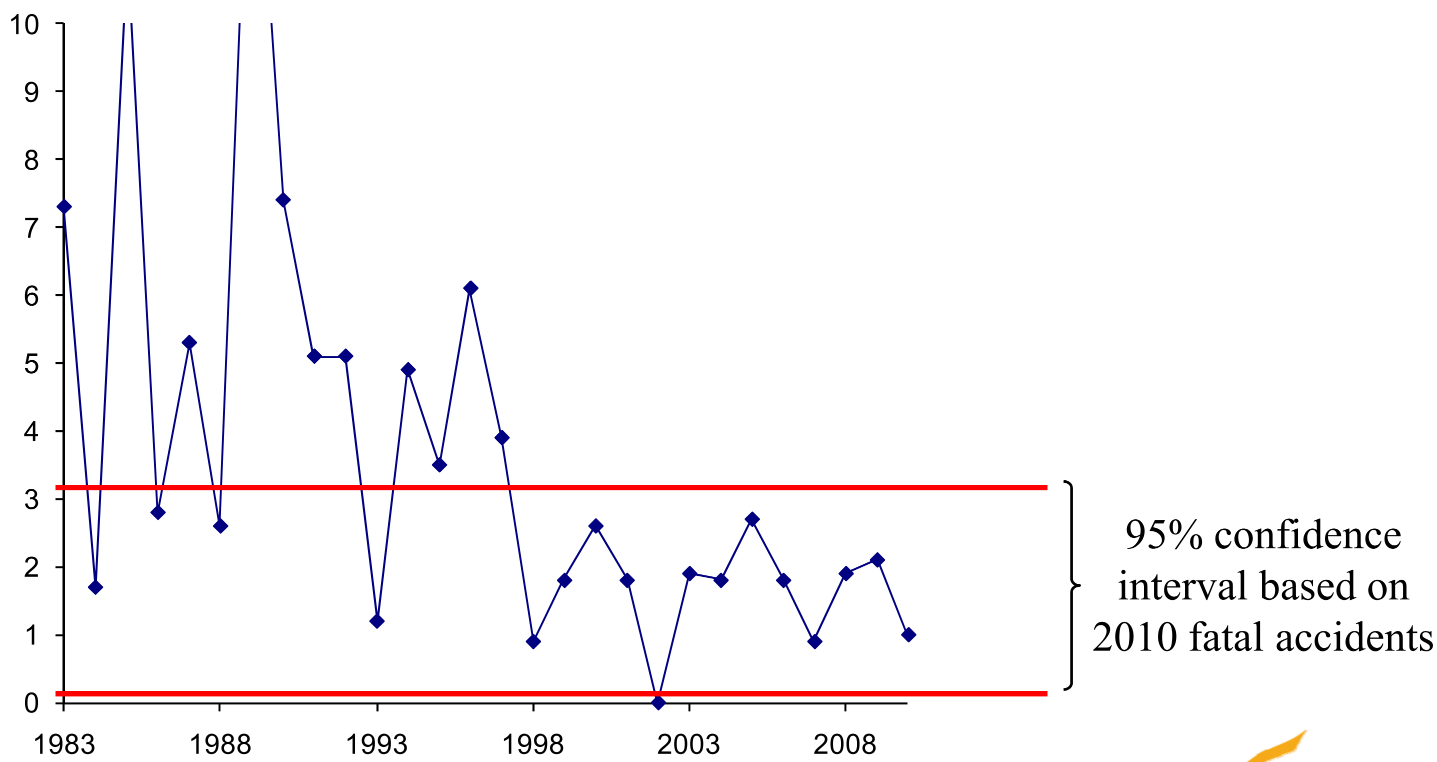


Data source: http://www.ntsb.gov/aviation/Stats.htm

Part 121

Fatal Accidents per 10,000,000 (10^7) Flight Hours:

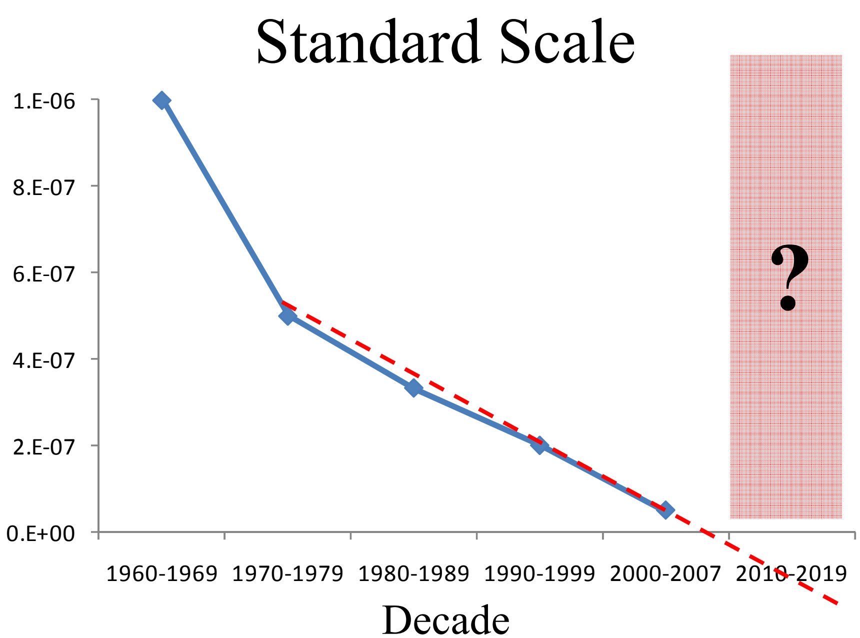
Part 121, Scheduled and Non-Scheduled (includes cargo)

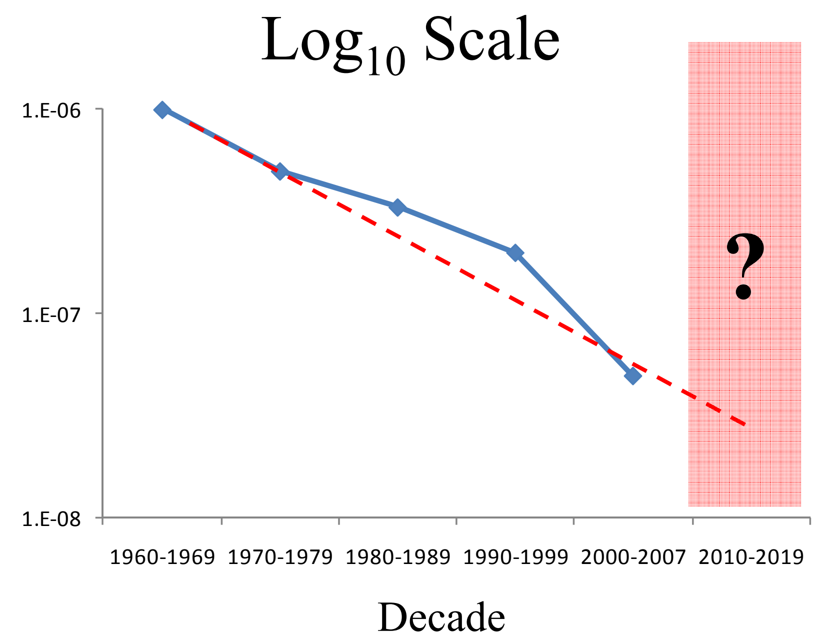


Data source: http://www.ntsb.gov/aviation/Stats.htm

Trends: Can We Get to Zero?

Barnett's passenger metric
First-world flights

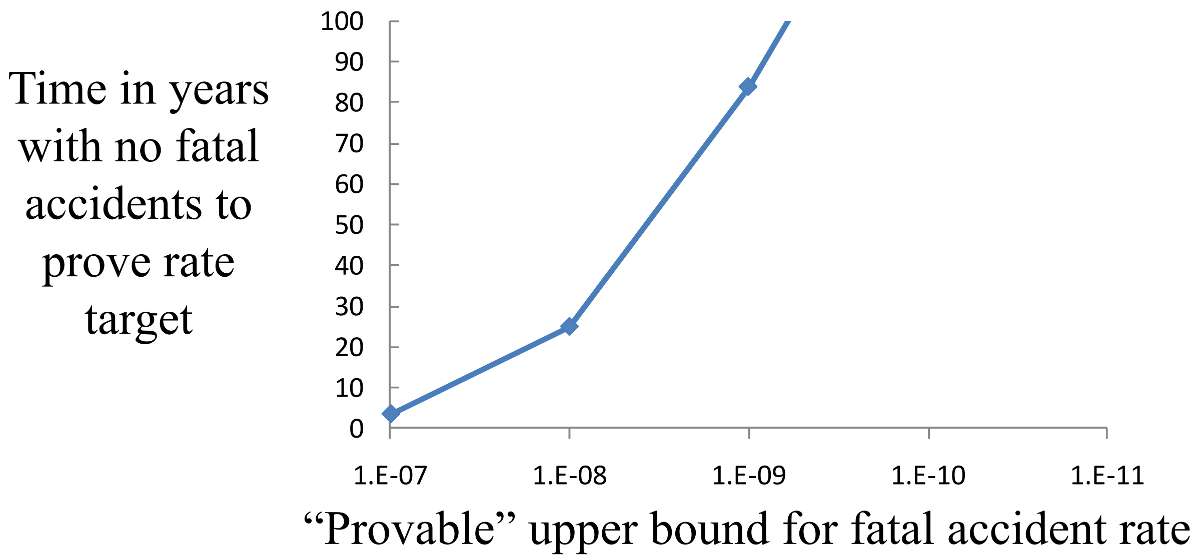




Barnett, A. 2008. Is it really safe to fly? *Tutorials in Operations Research*, 17-30.

Can We Prove a Zero Rate?

- Suppose there are *zero* fatal accidents from now on
- How long will it take to conclude – with 95% confidence – that the true accident rate is below 10^{-n}?
  - Assume 10^7 departures per year today (Part 121) and 3% annual growth



Observations

- Rare-event metrics are naturally shown on a logarithmic scale (e.g., 10^{-n})
- Difficult to get to *exactly* zero ($10^{-\infty}$)
  - Also difficult to prove the true accident rate is zero
- May be able to get low enough to be *effectively* zero.
- Aviation is already close
- Low absolute numbers make statistical conclusions more difficult
  - Good for “normal” people, bad for “statisticians”
  - Automobile statistics have similar *rates* (in order of magnitude), but much larger absolute numbers

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Challenges Going Forward

- Increasing capacity may require putting airplanes in closer proximity
- Changes must be shown to be safe
- Fatal accidents are so rare, it is hard to project the impact of changes based on historical data
- One approach: Investigate potential impact on *incidents* rather than accidents
  - But what is the correlation between incidents and accidents?
- Key question: As demand / capacity increase, what is the safety impact?

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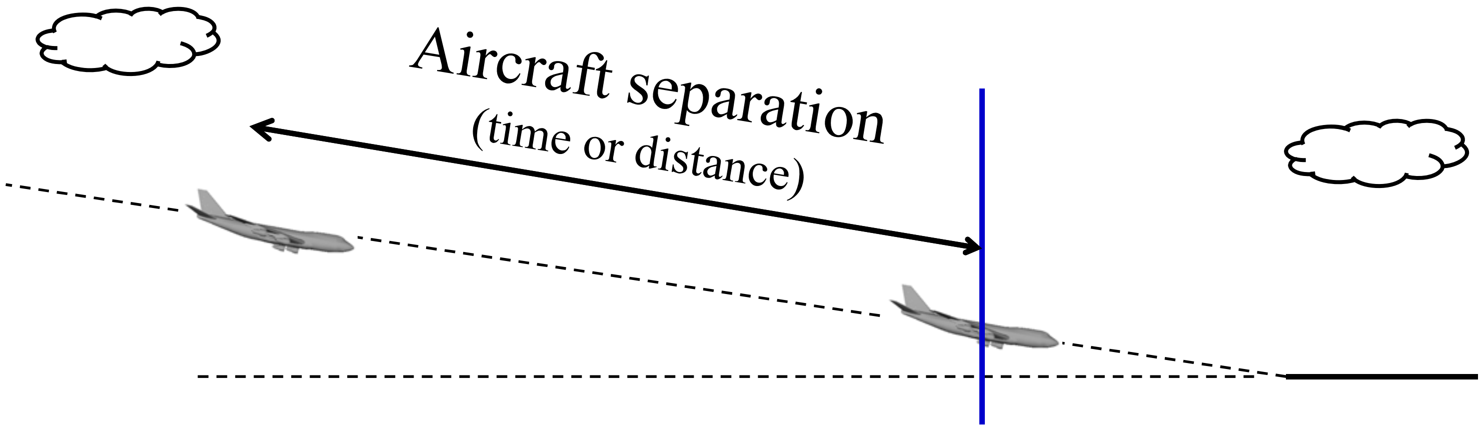
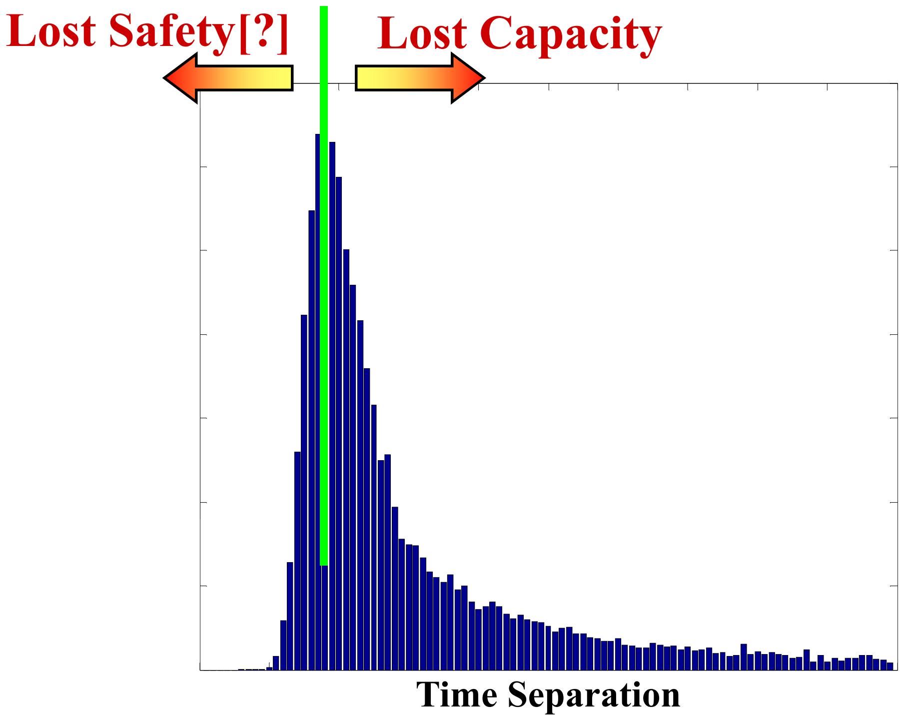
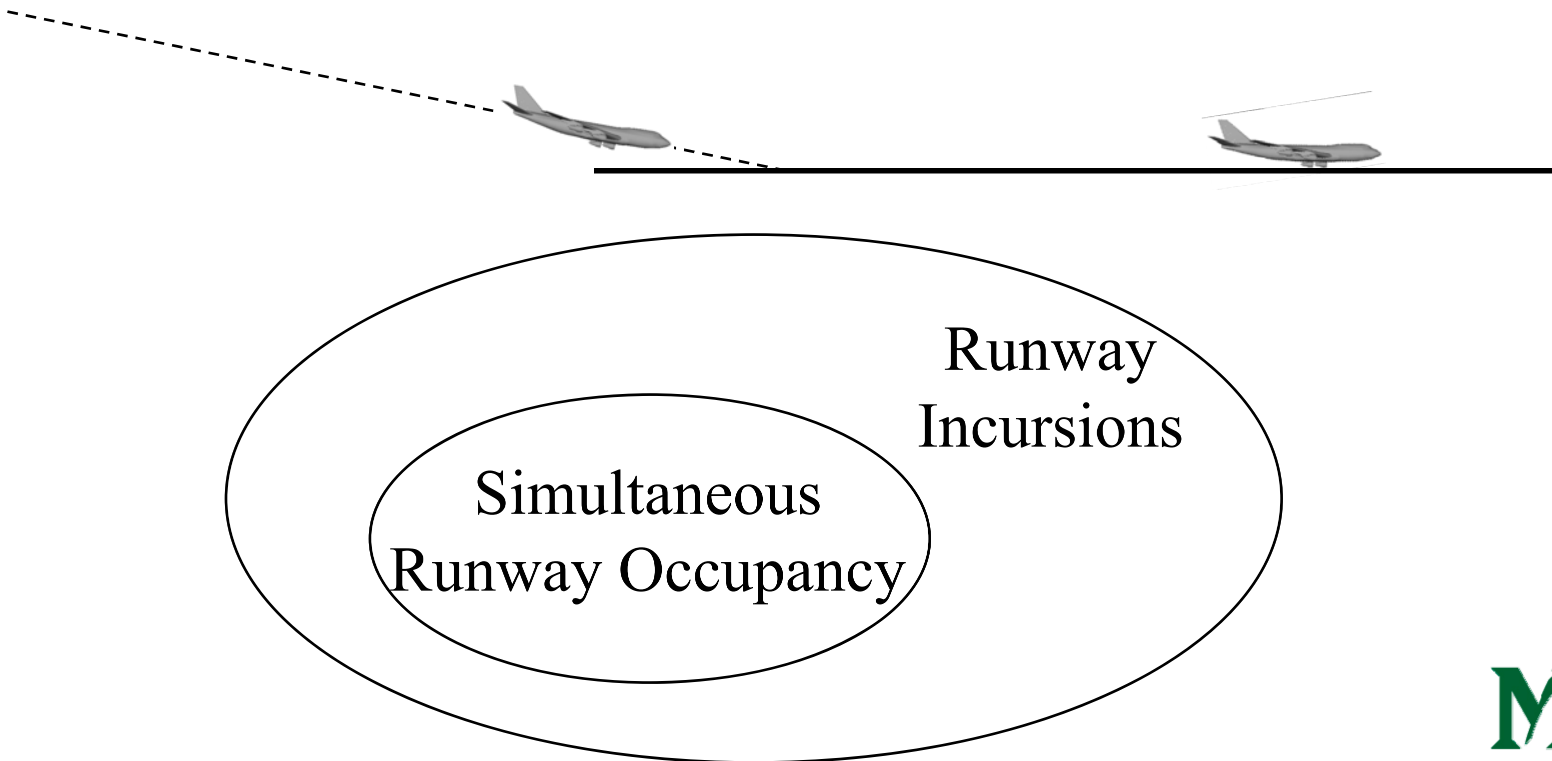
Safety-Capacity Tradeoff



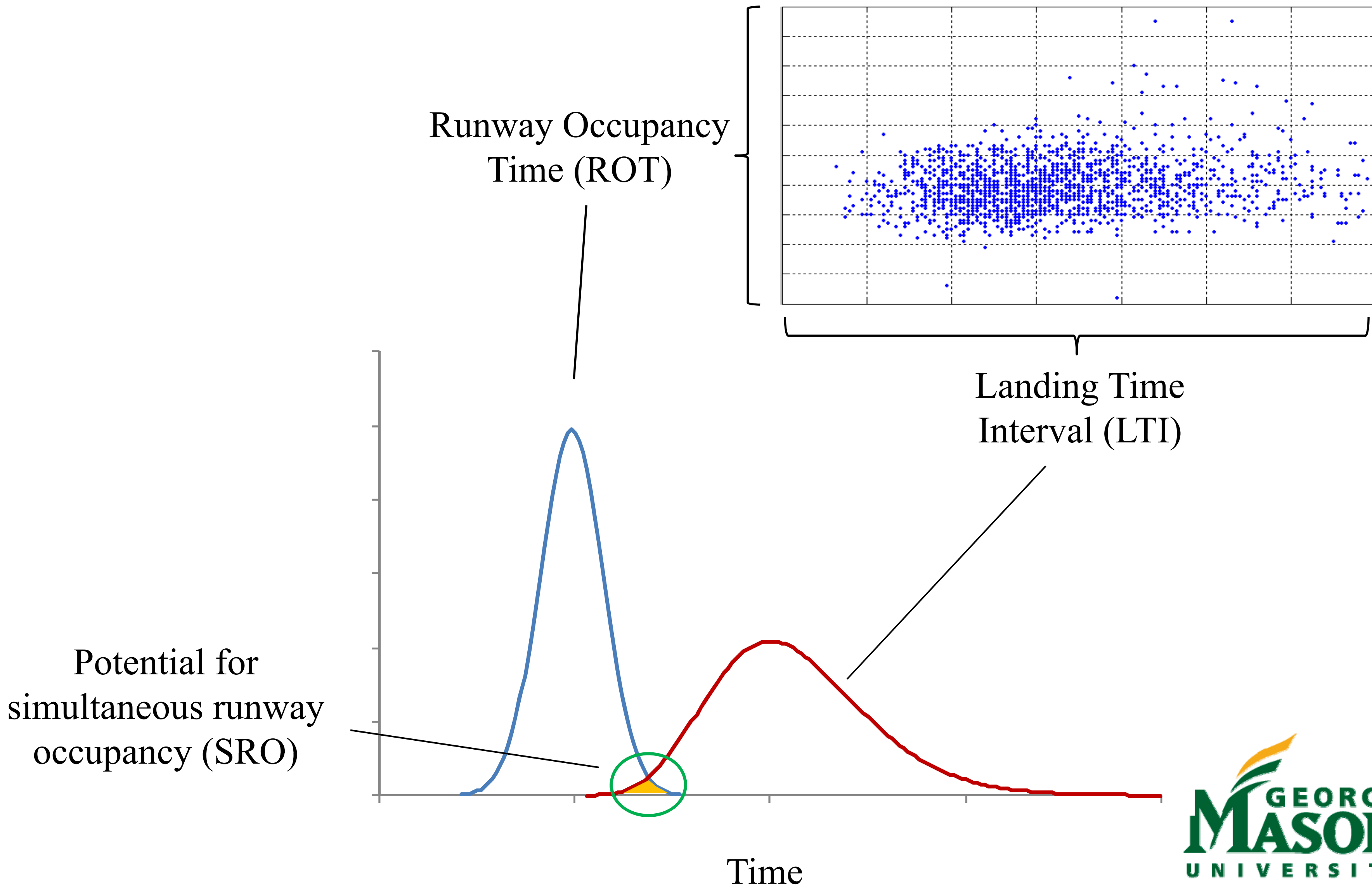


Runway Incursions

- Simultaneous runway occupancy (SRO). Trailing aircraft crosses threshold before leading aircraft is clear of the runway



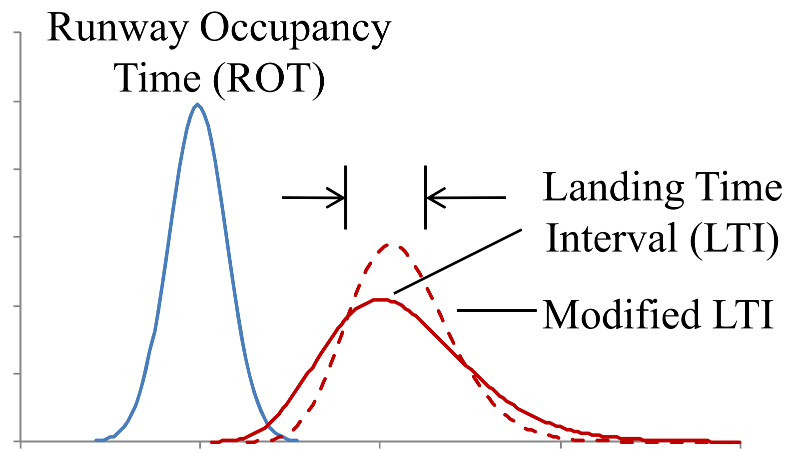
Simultaneous Runway Occupancy

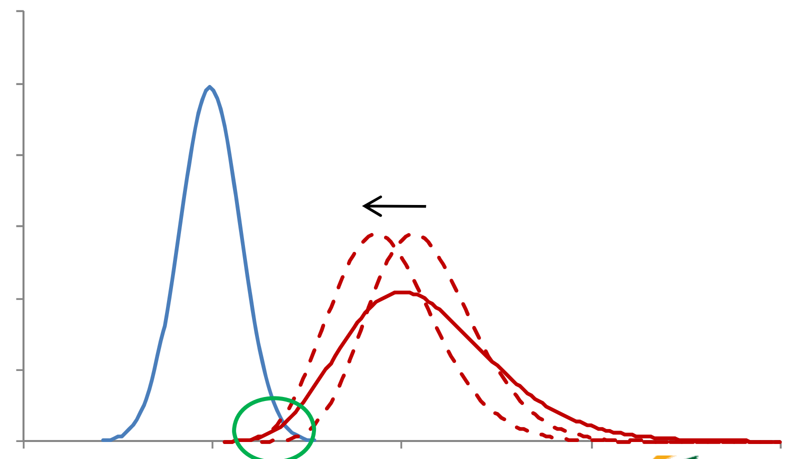


Safety-Capacity Impacts

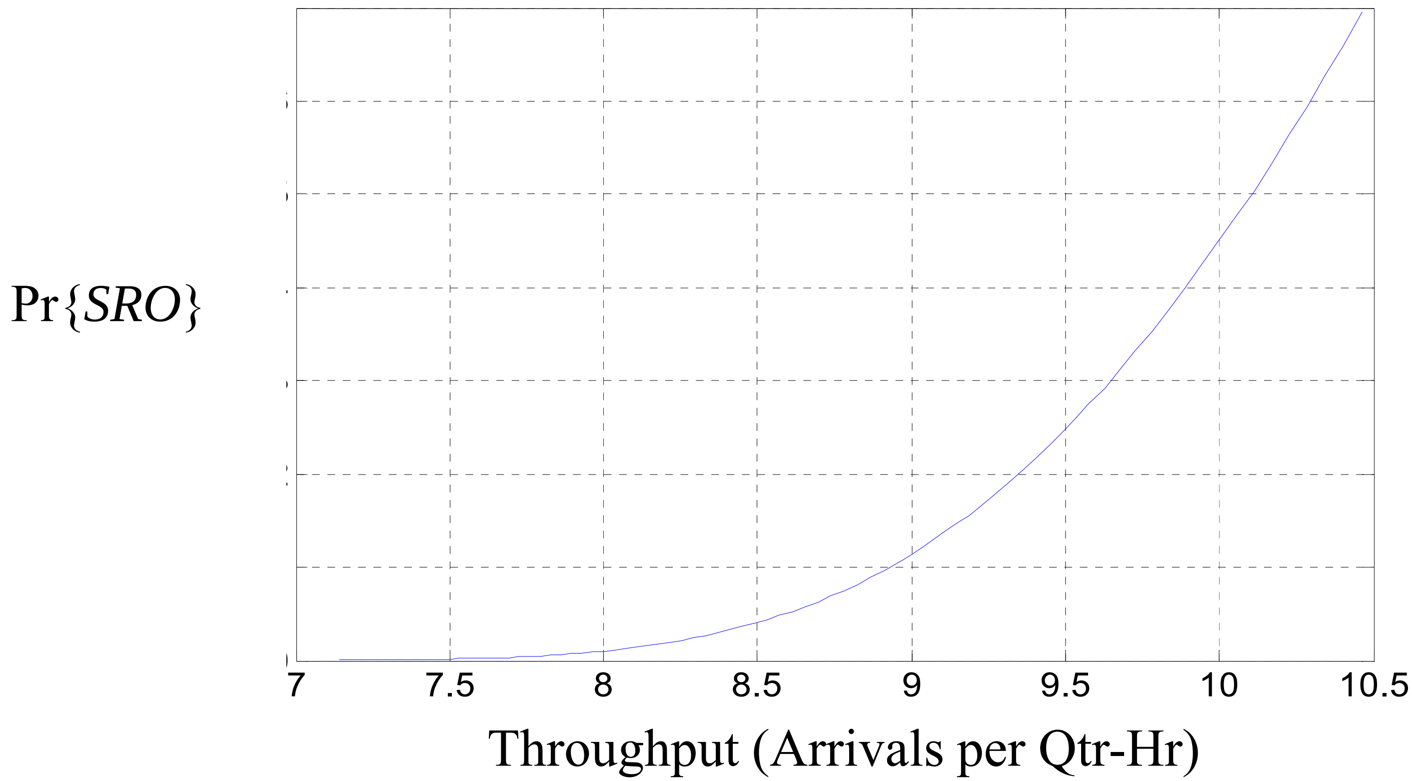
- Future technologies and procedures will seek to reduce the variance of the arrival time distribution

- This can allow an increase in capacity without a loss in safety





Risk vs. Throughput

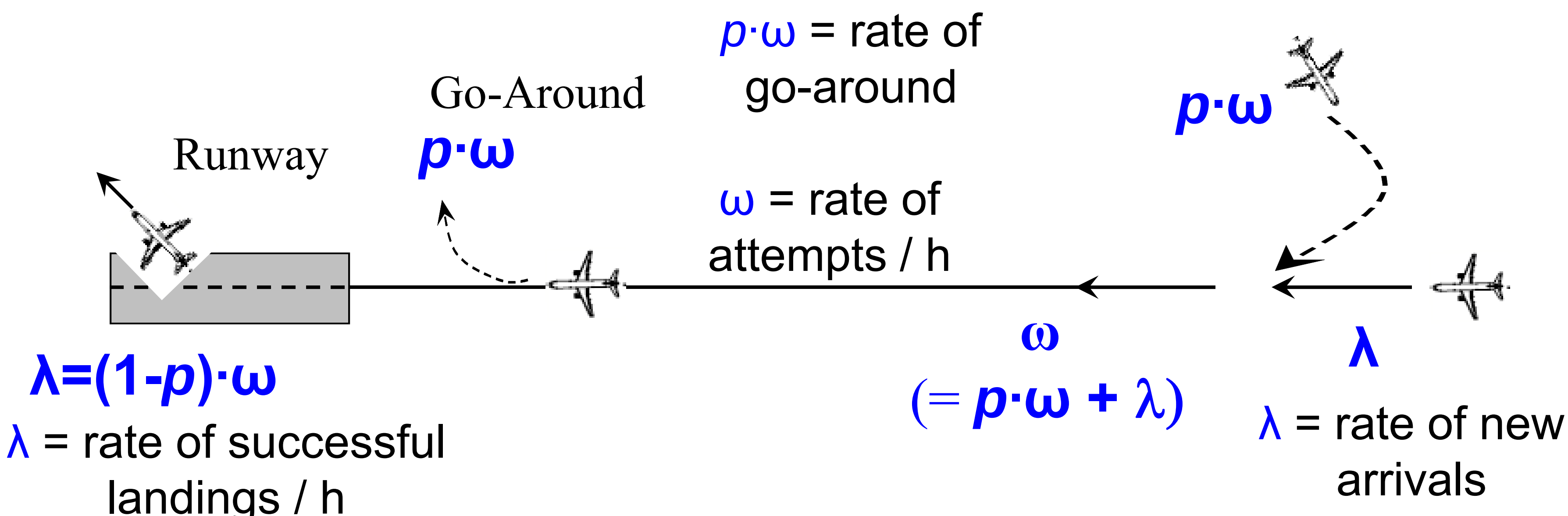


Jeddi, B., J. Shortle, L. Sherry. 2006. Statistical separation standards for the aircraft approach process. Proceedings of the 25th Digital Avionics Systems Conference, Portland OR, 2A1-2A1-13.

Risk-Free Capacity Definition

Assume **the system is** ***completely*** **safe** (safe = no SRO)

- Simultaneous runway occupancy (SRO) is eliminated by go-around
- Assume pilot *always* takes go-around to avoid SRO
  (perfect information & execution)



Goal: Maximize $\lambda(\omega) = [1-p(\omega)] \cdot \omega$

Jeddi, B., J. Shortle. 2007. Throughput, risk, and economic optimality of runway landing operations. *7th USA/Europe ATM R&D Seminar*, Barcelona, Spain, Paper 162.

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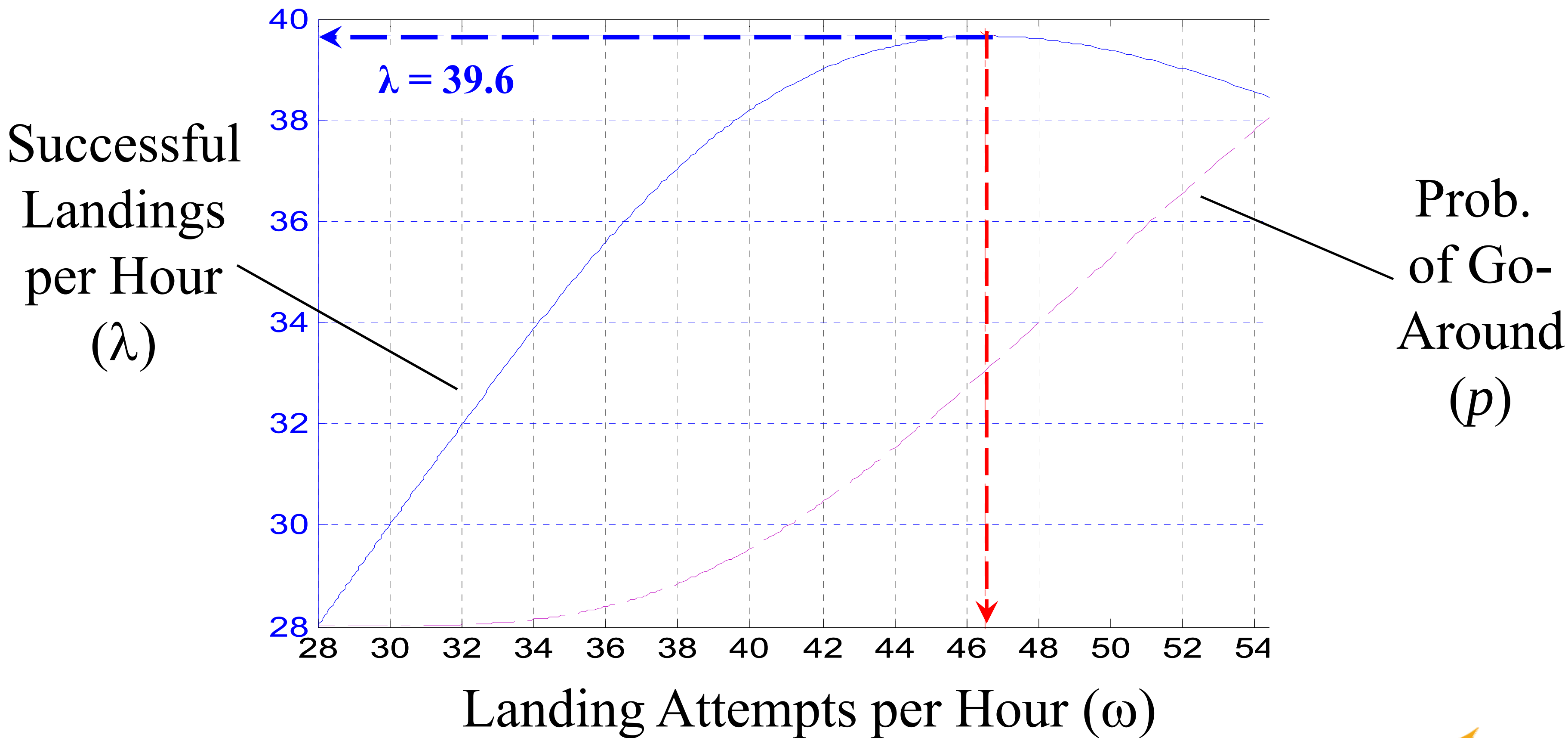
Maximizing Throughput



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Summary

- Fatal accidents are extremely rare (near extinction)
- Zero-accident rate may be hard to attain
  - And to prove, because of small statistical sample
- Increasing demand could spark a comeback
  - The accident *rate* must decrease just to maintain the *absolute* number of fatal accidents per year
  - Putting aircraft closer together must be shown to be safe
- Incident analysis shows tradeoff between capacity and safety for potential system changes
  - But modeling fatal accident rate remains a challenge

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