# Wake Procedures in the US and the Potential Capacity Benefit

## WakeNet3 Capacity Workshop (London)

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# Executive Summary

- **There are many capacity-increasing concepts in the U.S. in different stages of development**
  - Some increase IFR capacity, others increase VMC capacity
- **There are multiple methods of approving a change to existing separation standards**
  - This presentation shows the benefits work being done for two different changes
- **Safety, cost / benefit analysis, required automation, and stakeholder acceptance are all concerns that must be satisfactorily addressed**

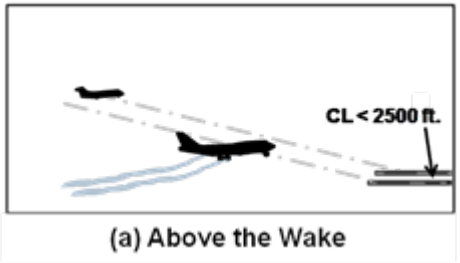
# Agenda

- Overview of US Concepts
- RECAT Analysis
- WTMD Analysis
- Difficult-to-model Benefits

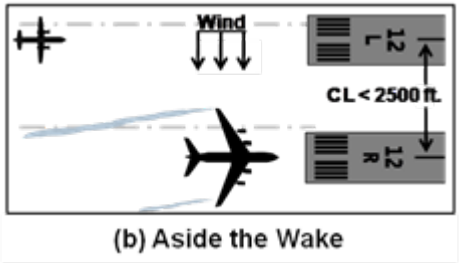
# Overview of active U.S. concepts

- **Most U.S. wake-related concepts are focused on closely spaced parallel runways, which are prevalent in the U.S.**
  - All U.S. airports run visual operations when able, significantly increase airport capacity
- **Same-runway concepts are being developed**

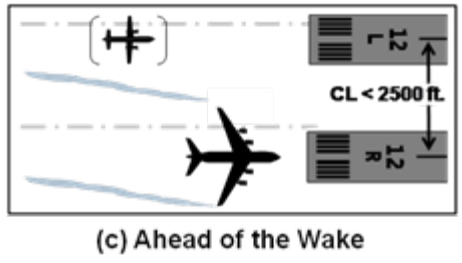
**Methods for Avoiding a Wake Vortex**



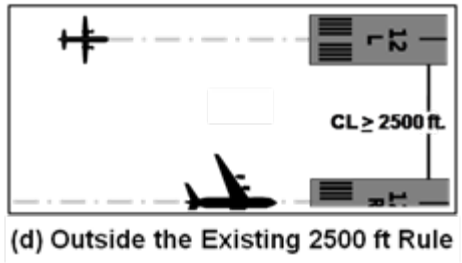
(a) Above the Wake



(b) Aside the Wake



(c) Ahead of the Wake



(d) Outside the Existing 2500 ft Rule

# Capacity Analysis Research Needs

- **7110.308**
  - Airport/Facility/User requests for assessment
  - Clear indication when procedure is in use
- **Wake Turbulence Mitigation for Departures (WTMD) – Trial Implementation Begins 04/2011**
  - Airport winds (crosswind availability and stability)
  - ATC and User Participation
- **Recategorization of Wake Turbulence Categories (RECAT) – Pending ICAO Approval**
  - User support
  - ANSP participation
- **Wake Turbulence Mitigation for Arrivals – Procedure (WTMA-P) – Concept Development**
  - Wake turbulence data for Heavy and B757 Aircraft as function of winds
  - Airport local winds and geometry
  - National level ATC and user support
- **Wake Turbulence Mitigation for Arrivals – System (WTMA-S) – System Development**
  - Combined requirements of WTMA-P and WTMD

# Research Needs Grow with the Maturity of the Concept

- **WTMD in initial concept stage, initial airport downselect**
  - % time surface winds were above a threshold
  - % fleet mix
- **WTMD acquisition phases**
  - Added winds aloft
  - Added seasonal and time of day variations
  - Added working version of wind forecast algorithm
  - ASDE-X data
  - Correlated departure demand and procedure availability
- **WTMD operational demonstration phase**
  - Visual Observation for a few weeks
  - Post-hoc benefits analysis at demo sites
  - Availability vs. Use
  - Verify procedure operates as designed

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- **RECAT Analysis**
- WTMD Analysis
- Difficult-to-model Benefits

# Levels of Analysis Fidelity

## Average Required Minimum Separation Distance (*AvgMinSep*)

| Leading Aircraft \ Trailing Aircraft | CatA | CatB | CatC | CatD | CatE | CatF |
|---|---|---|---|---|---|---|
| CatA | 2.5 | 6 | 6 | 7 | 7 | 8 |
| CatB | 2.5 | 3 | 4 | 5 | 5 | 7 |
| CatC | 2.5 | 2.5 | 2.5 | 3.5 | 3.5 | 6 |
| CatD | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 5 |
| CatE | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 4 |
| CatF | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |

X

| Leading Aircraft \ Trailing Aircraft | CatA | CatB | CatC | CatD | CatE | CatF |
|---|---|---|---|---|---|---|
| CatA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CatB | 0.00% | 0.03% | 0.06% | 1.05% | 0.59% | 0.04% |
| CatC | 0.00% | 0.06% | 0.13% | 2.11% | 1.19% | 0.08% |
| CatD | 0.00% | 1.05% | 2.11% | 34.80% | 19.70% | 1.33% |
| CatE | 0.00% | 0.59% | 1.19% | 19.70% | 11.16% | 0.75% |
| CatF | 0.00% | 0.04% | 0.08% | 1.33% | 0.75% | 0.05% |

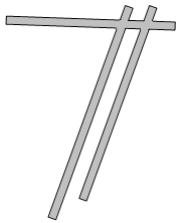
= **2.6245 nm**

- Easy to apply to many airports
- Fast turnaround
- Very high level

## Airport Capacity Simulation with *runway*Simulator (*r*S)

Fleet Mix

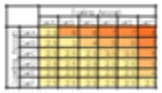
Airport Layout



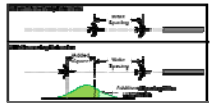
Rules

1.Heavy aircraft shall…
2.Departing Small aircraft shall…
3.Converging aircraft…
4.Runway 27 shall not be used for…

Separations



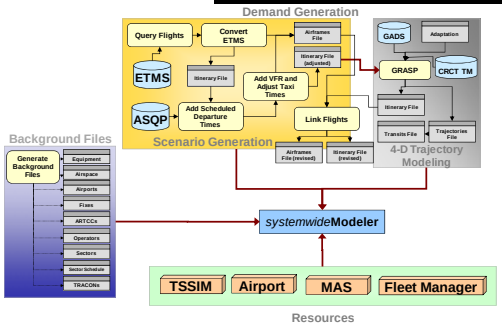
Delivery Uncertainty



X Average of Hundreds of Hours = **35.78 Arrivals per Hour**

- Many additional factors considered
- Easy to understand metric
- More realistic benefits estimates

## NAS-wide Delay Analysis with *systemwide*Modeler (*s*M)

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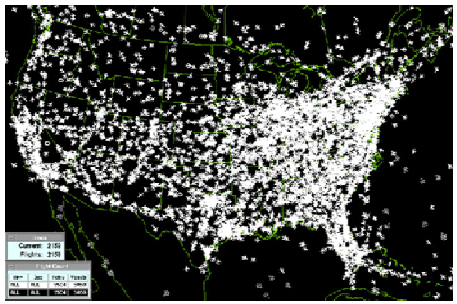
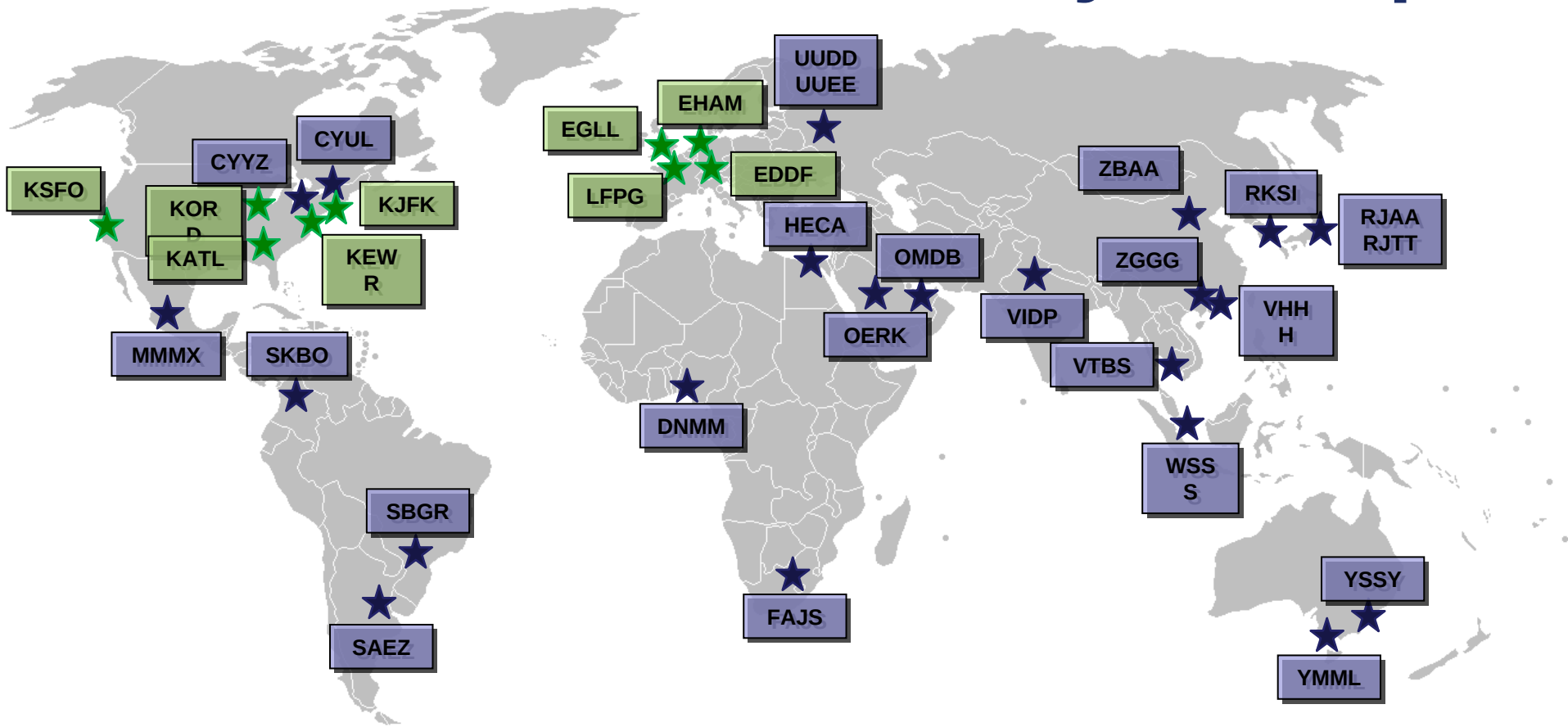


= **20,253,982 Minutes of Delay**

- Comprehensive network delay metric
- Significant setup and analysis required
- Monetization of benefits possible

# Worldwide RECAT Analysis Map

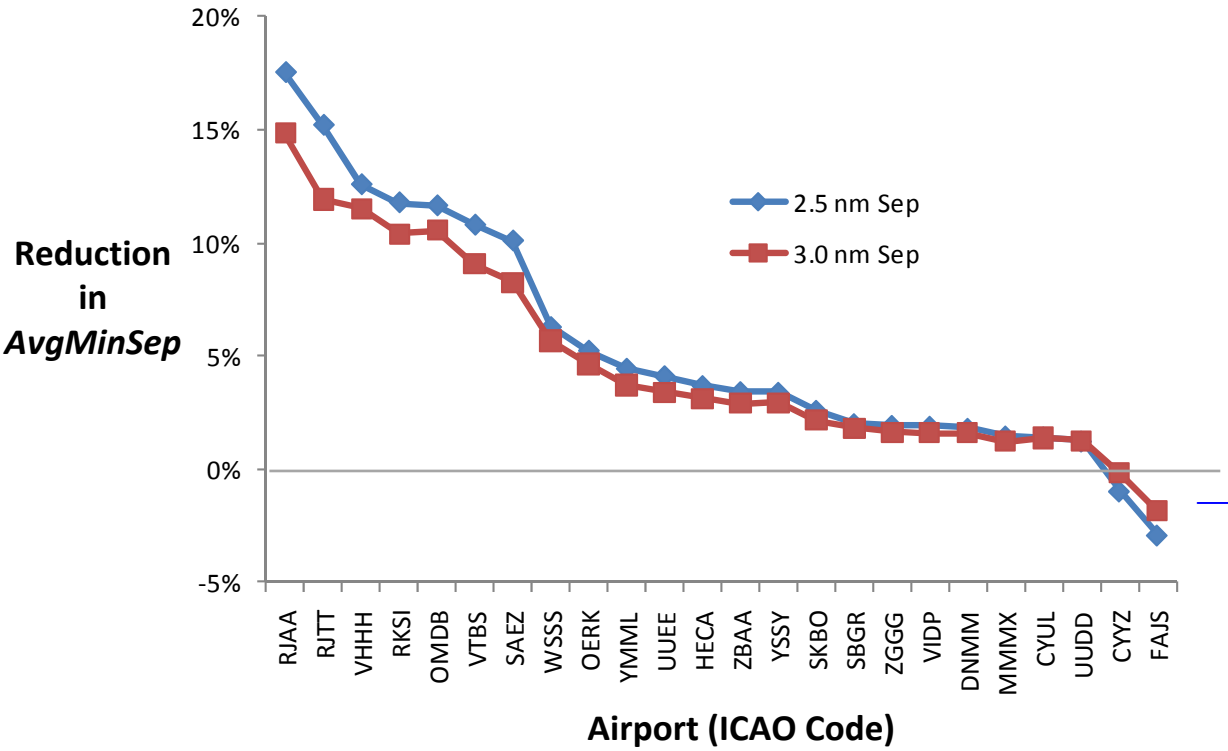



- Airports selected for detailed analysis (Green)
- Additional airports analyzed to confirm benefits (Blue)



Source: http://commons.wikimedia.org/wiki/File:BlankMap-World-v2.png

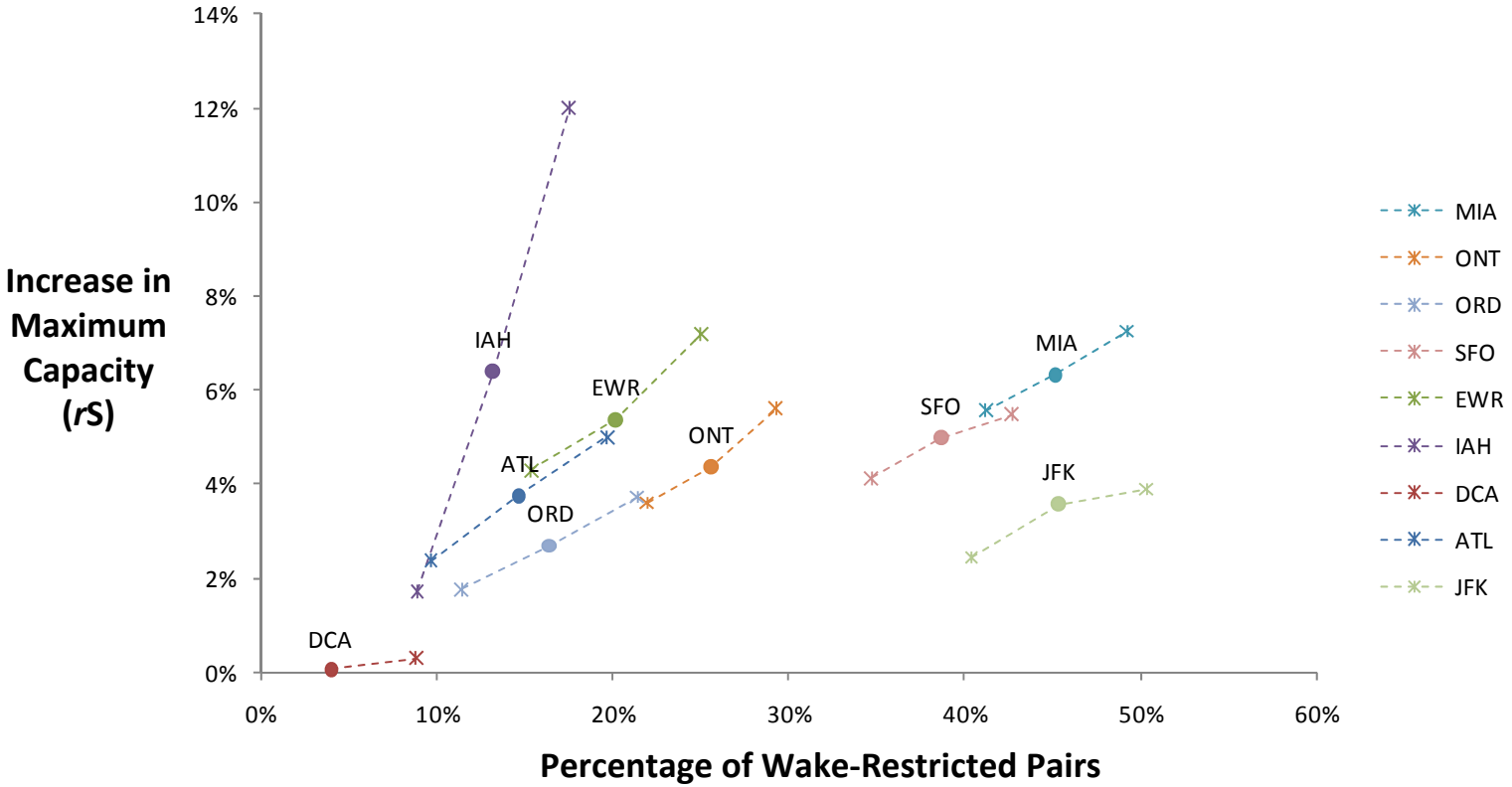
# Worldwide RECAT Benefits (*AvgMinSep*)




- Neutral to CYYZ
- FAJS not capacity constrained
- No ANSP is required to transition to RECAT Phase I
- Unique needs of individual airports provided for in RECAT Phase II

- **This analysis was conducted using OAG data from Fiscal Year 2010.**
  - OAG data is only scheduled flights, and doesn't include cargo, military, or GA flights

# U.S. Airport RECAT Benefits (*r*S)




- **IAH's independent runways lead to a steeper relationship than other airports with arrival-departure runway dependencies**



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# U.S. Airport RECAT Benefits (sM)

- **A network delay analysis is currently underway using *systemwide*Modeler**
  - This analysis requires *r*S simualtions of 58 airports under 3 weather conditions for baseline and treatment cases
  - Uses traffic schedules, fleet mixes and actual weather data
  - Detailed - can swap airframes, issue GDPs, etc.
- **The network-wide delay will allow the trickle-down effect of delay and delay mitigation to be evaluated**
- **The monetization of the reduction in delay between the baseline and the treatment case is an estimate for benefits for the treatment**

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# WTMD Capacity Analysis

- **The FAA Acquisition Management System (AMS) requires an incremental benefit analysis**
  - Shortfall Analysis – Estimate of how large the problem is and how much of it WTMD will address
  - Investment Analysis (Initial and Final) – Is the benefit of WTMD worth the cost of implementing and operating it
  - Methods:  Analysis, simulation, operational demonstration

# Benefits Estimation Methods

| | Airport Capacity Simulation with runwaySimulator | Day in the Life Analysis |
|---|---|---|
| **Output Goal** | Runway Capacity Enhancement Independent of Current Scheduled Demand | Estimate Additional Departures Enabled by WTMD |
| **Methodology** | Detailed Simulated Airport Operations Combined with Annual Wind Forecasting Algorithm Outputs | Historical Look at the Number of Heavy and B757 Departures During WTMD Periods |
| **Traffic Demand Level** | Constant, high demand. Current day traffic mix | Current Demand Levels |
| **Analysis Time Range** | One Year | One Year |
| **Additional Analysis Output** | Airport Operations Visualization (Final Approach, Initial Departure, Arrival/Departure Queues) | Correlation of WTMD Periods with Heavy and B757 Departures |

- **The two methods provided complementary perspectives on WTMD capacity:**
  - Day in the Life provides a benchmark of capacity increase with current day demand
  - Capacity Simulation estimates future capacity when demand increases

# Three Airport Sample - Summary of Delay Savings with WTMD

| Airport | Wind Forecast Algorithm Green Minutes | Heavy/B757 Departures | Heavy/B757 Departures During Green | With Operational Day, Ceiling/Visibility, Compatible Runway Direction | Heavy/B757 Departures no longer creating wake delay (random runway) |
|---|---|---|---|---|---|
| DTW | 92575 | 25433 | 4860 | 3967 | 1984 |
| EWR | 110579 | 48429 | 10914 | 10008 | 5000 |
| PHL | 78925 | 28126 | 4440 | 4289 | 2145 |

| WTMD Airport | Heavies after all impacts | Avg Queue per runway | Avg Queue Until Empty per runway | Aircraft Impacted | Annual Hours of delay savings | 2007 Annual Benefit $M (BY 2008) | Lifecycle (2011-2030) Benefits $M (BY 2008) | Lifecycle (2011-2030) Benefits $M (PV) |
|---|---|---|---|---|---|---|---|---|
| DTW | 1984 | 3.37 | 6.74 | 13372 | 432 | $1.36 | $35.97 | $15.94 |
| EWR | 5000 | 4.65 | 9.29 | 46450 | 1502 | $4.84 | $133.51 | $58.69 |
| PHL | 2145 | 3.81 | 7.62 | 16345 | 528 | $1.57 | $45.03 | $19.64 |
| Total | | | | | | | $214.51 | $94.27 |

# WTMD Candidate Airports – Estimated Departures per Day No Longer Incurring Wake Delay


WTMD Candidate Airports Shown in WHITE



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# Some benefits are hard to model

- **The detail of a model is proportional to the effort required to model it**
  - E.g., very detailed models are required for taxiway crossings
- **A procedure might enable flexibility in airport operations not allowed by current procedures**
- **Reduced separations mean fewer controller work-arounds are needed to optimize the system**

# Conclusions

- **Many concepts show benefits in the U.S.**
  - WTMD and RECAT benefits have been shown using different methodologies
- **Benefits must be accurate and easy to explain**
  - Without stakeholder acceptance, new procedures will not be used, and benefits will be left unclaimed
- **Increased capacity is not the only benefit**
  - Other benefits (increased flexibility, reduced controller workload, increased procedure acceptance) are more difficult to model, but no less important

# Backup

# Many airports were examined for international benefits

## List of Airports Analyzed

| ICAO Code | IATA Code | Airport Name | Location | Arrivals in Data |
|---|---|---|---|---|
| ZBAA | PEK | Beijing/Captial International | Beijing, China | 256,879 |
| CYYZ | YYZ | Lester B Pearson International | Toronto, Canada | 189,840 |
| RJTT | HND | Tokyo Haneda International | Tokyo, Japan | 181,448 |
| ZGGG | CAN | Guangzhou Baiyun International | Guangzhou, China | 163,331 |
| MMMX | MEX | Benito Juarez International | Mexico City, Mexico | 163,036 |
| YSSY | SYD | Kingsford Smith | Sydney, Australia | 153,442 |
| VHHH | HKG | Hong Kong International | Hong Kong, China | 139,466 |
| OMDB | DXB | Dubai International | Dubai, United Arab Emirates | 130,417 |
| VTBS | BKK | Suvarnabhumi International | Bangkok, Thailand | 128,763 |
| WSSS | SIN | Singapore Changi International | Singapore, Singapore | 125,232 |
| VIDP | DEL | Indira Gandhi International | New Delhi, India | 122,893 |
| SKBO | BOG | El Dorado International | Bogota, Columbia | 108,559 |
| YMML | MEL | Melbourne Airport | Melbourne, Australia | 103,353 |
| SBGR | GRU | Guarulhos International | Sao Paulo, Brazil | 100,692 |
| RKSI | ICN | Incheon International | Seoul, South Korea | 99,521 |
| FAJS | JNB | OR Tambo International | Johannesburg, South Africa | 97,572 |
| RJAA | NRT | Narita International | Tokyo, Japan | 92,988 |
| UUDD | DME | Domodedovo International | Moscow, Russia | 90,901 |
| UUEE | SVO | Sheremetyevo International | Moscow, Russia | 84,761 |
| CYUL | YUL | Montreal-Pierre Elliot Trudeau International | Montreal, Canada | 83,961 |
| HECA | CAI | Cairo International | Cairo, Egypt | 61,196 |
| OERK | RUH | King Khalid International | Riyadh, Saudi Arabia | 49,652 |
| DNMM | LOS | Murtala Muhammed International | Lagos, Nigeria | 37,847 |
| SAEZ | EZE | Ministro Pistarini International | Buenos Aires, Argentina | 27,284 |