



CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Analysis of Wind Dependent Conops for Capacity, Opportunity, and Ranking

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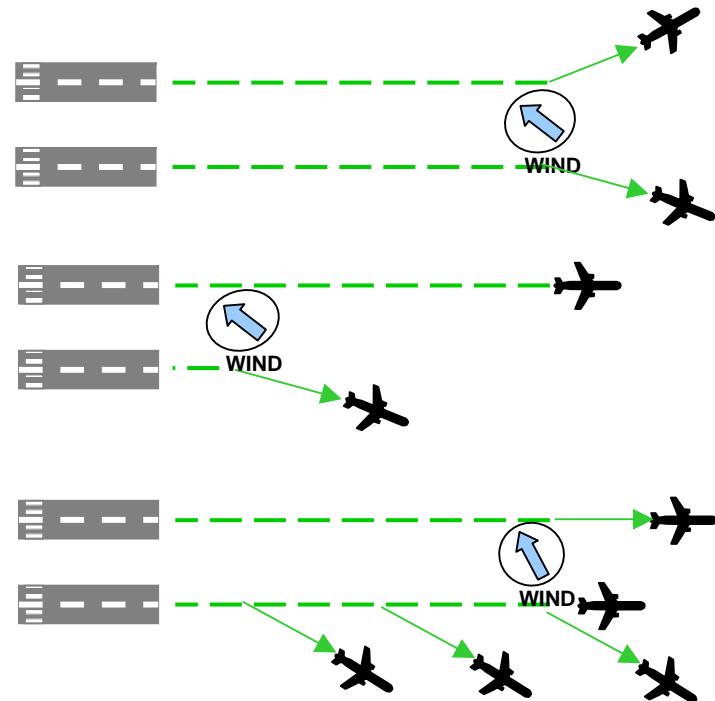
Outline

- **Capacity Analysis Overview**
 - CET Conops Overview
 - Simulation method
 - Capacity Results for Ranking Conops
- **Opportunity (Availability of Required Winds)**
 - RUC data processing overview
 - Hourly wind profile characteristics
 - ASZ heights and crosswind thresholds for conops
 - Percent of time required winds exist at 20 airports
- **Other Conop Ranking Considerations**
 - Certification
 - Transition
 - Stakeholder acceptance
 - Another view on research difficulty and cost ranking



Conops Team Departure Options

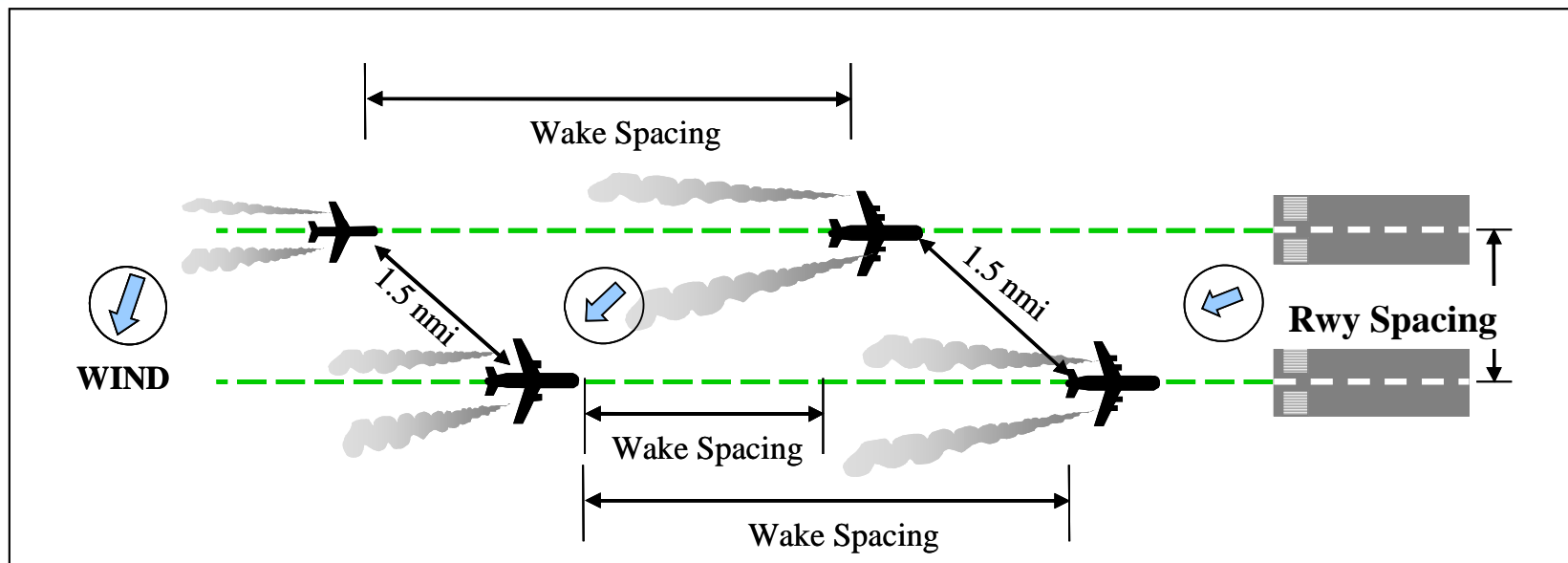
- Both runways depart straight-out to 5 nmi
- Downwind runway departs straight-out, upwind runway departure diverges upwind at 1 nmi
- Downwind runway departs straight-out, upwind runway has multiple points where departures can diverge upwind



- Upwind runway wake-free relative to departures from downwind runway
- Same runway wake sep applied on both runways in options 1 and 2
- Option 3 also reduces same runway wake sep on upwind for diverging departures
- Similar geometries proposed by CET for single runway departures



Conops Team Arrival Options



- **Straight-in, 10-20 nmi final**
- **Angled 3 degree approaches to MAP**
- **Angled 3 degree approaches to FAF**
- **Alternating LDAs (up to 30 degrees) to MAP**
- **One straight-in, one 3 degree angled approach**
- **Similar geometries for single runway arrival options**



Capacity Estimation for Ranking Conops



Capacity Simulation

- **Monte Carlo simulations using distributions derived from operational data**
 - Traffic mix
 - Approach speeds
 - Final approach spacing
 - Spacing uncertainty buffer
- **50,000 aircraft operations modeled for each conop**
- **Explored sensitivity of capacity benefits to**
 - Assigning Heavy Jets and B757s to downwind runway
 - Conop options limiting wake spacing reduction behind certain leaders
- **Same simulation process used in support of FAA's proposed near term procedure analysis**



Airports Modeled

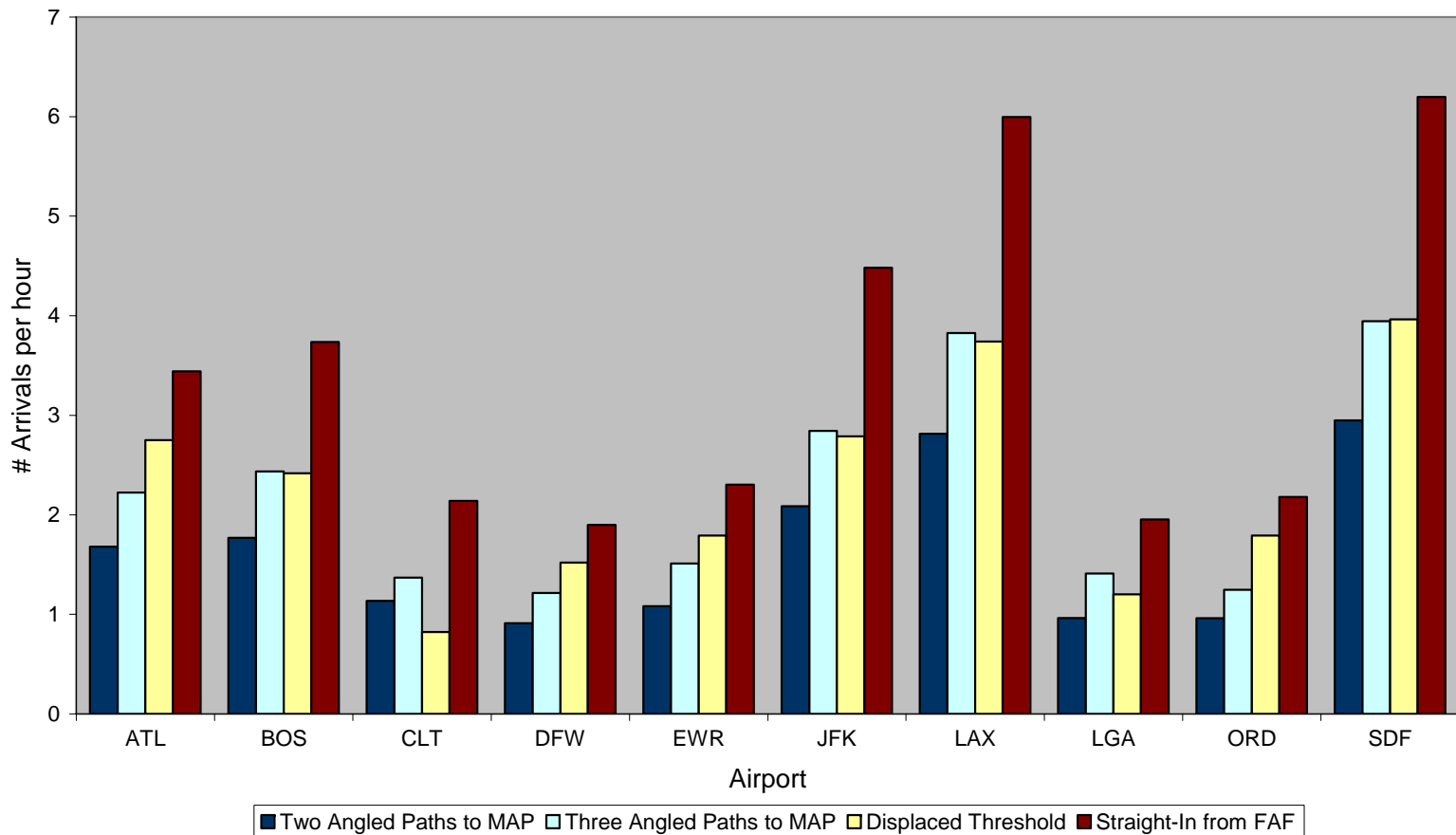
Airport	ATL	BOS	CLE	CLT	DFW	DTW	EWR	FLL	IAH	JFK
Heavy	10.9%	6.5%	1.0%	1.4%	4.1%	2.5%	12.2%	4.3%	4.6%	32.6%
B757	6.8%	10.9%	1.1%	3.9%	5.6%	6.6%	9.6%	11.1%	4.8%	12.0%
Large	81.1%	74.4%	86.0%	84.1%	88.7%	90.1%	77.4%	70.1%	87.1%	53.6%
Small	1.3%	8.3%	12.0%	10.6%	1.6%	0.8%	0.9%	14.5%	3.5%	1.7%
CSPR Rwy Spacing	1050	1500	1241	NA	1200	2000	900	NA	1000	NA
Min Arr Sep	2.5	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0
OEP List	*	*	*	*	*	*	*		*	*
OPSNET List	*	*	*	*	*	*	*	*	*	*
2013 List							*	*		*
Run CSPR Deps	D	D	D		D	D	D		D	
Run CSPR Arrs		A	A			A	A			
Run Single Runway	S	S		S	S		S			S

Airport	LAX	LGA	MEM	MIA	ORD	PHL	SDF	SEA	SFO	STL
Heavy	18.5%	0.9%	20.9%	17.5%	6.5%	5.5%	21.7%	4.8%	16.8%	0.7%
B757	10.8%	8.3%	0.8%	13.8%	5.2%	6.0%	9.8%	6.8%	14.0%	2.3%
Large	59.8%	84.6%	67.3%	61.7%	87.5%	85.9%	59.6%	84.2%	58.0%	88.3%
Small	10.9%	6.2%	11.0%	6.9%	0.8%	2.6%	8.9%	4.3%	11.2%	8.8%
CSPR Rwy Spacing	700	NA	926	800	NA	1400	NA	800	750	1300
Min Arr Sep	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.0	2.5
OEP List	*	*	*	*	*	*		*	*	*
OPSNET List	*	*	*	*	*	*		*	*	*
2013 List		*			*	*				
Run CSPR Deps	D		D	D		D		D	D	D
Run CSPR Arrs	A					A		A	A	A
Run Single Runway	S	S			S		S			



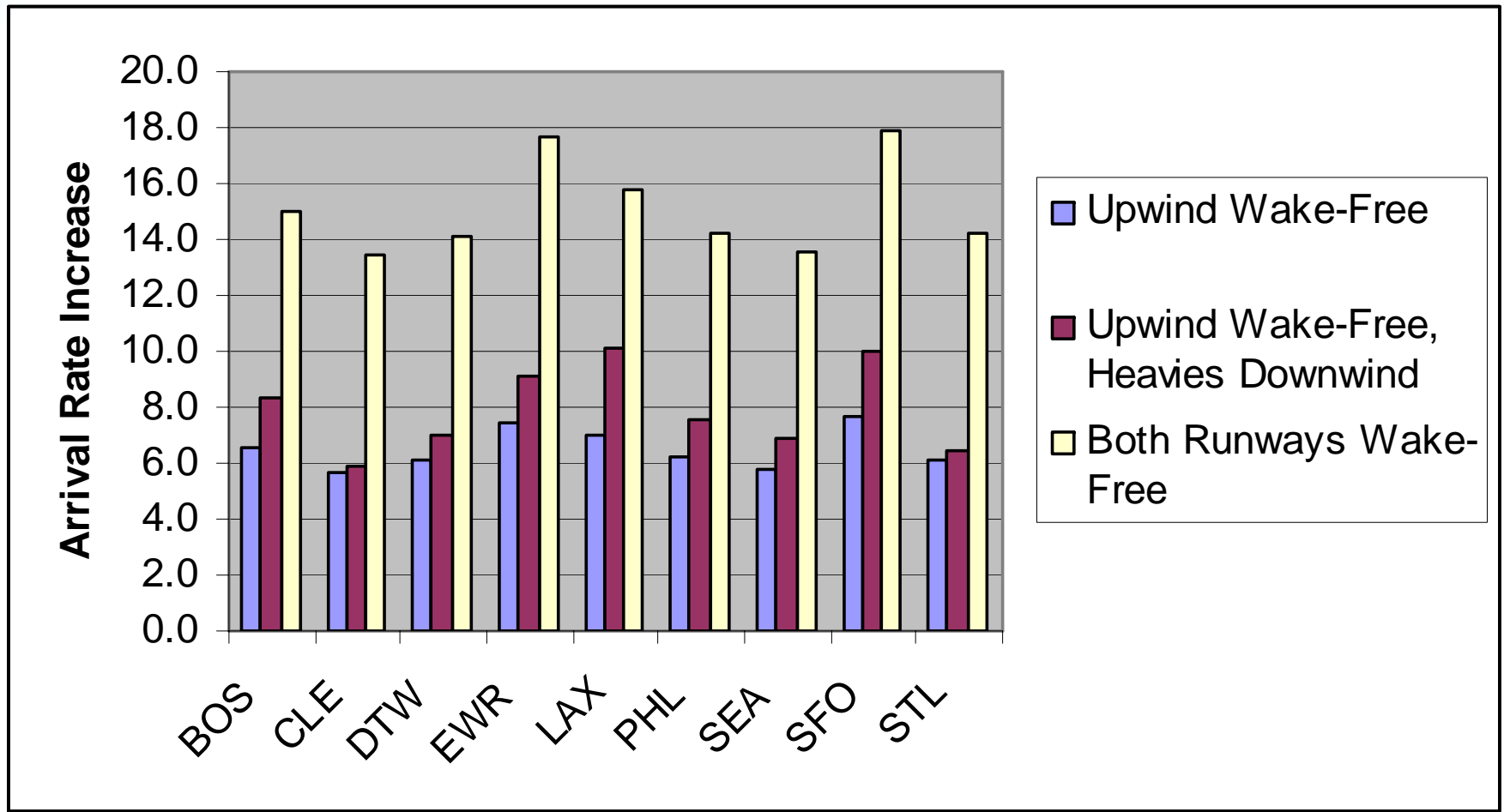
Single Runway Arrival Results (2.5/3.0 nmi)

Mean Capacity Increase per Procedure



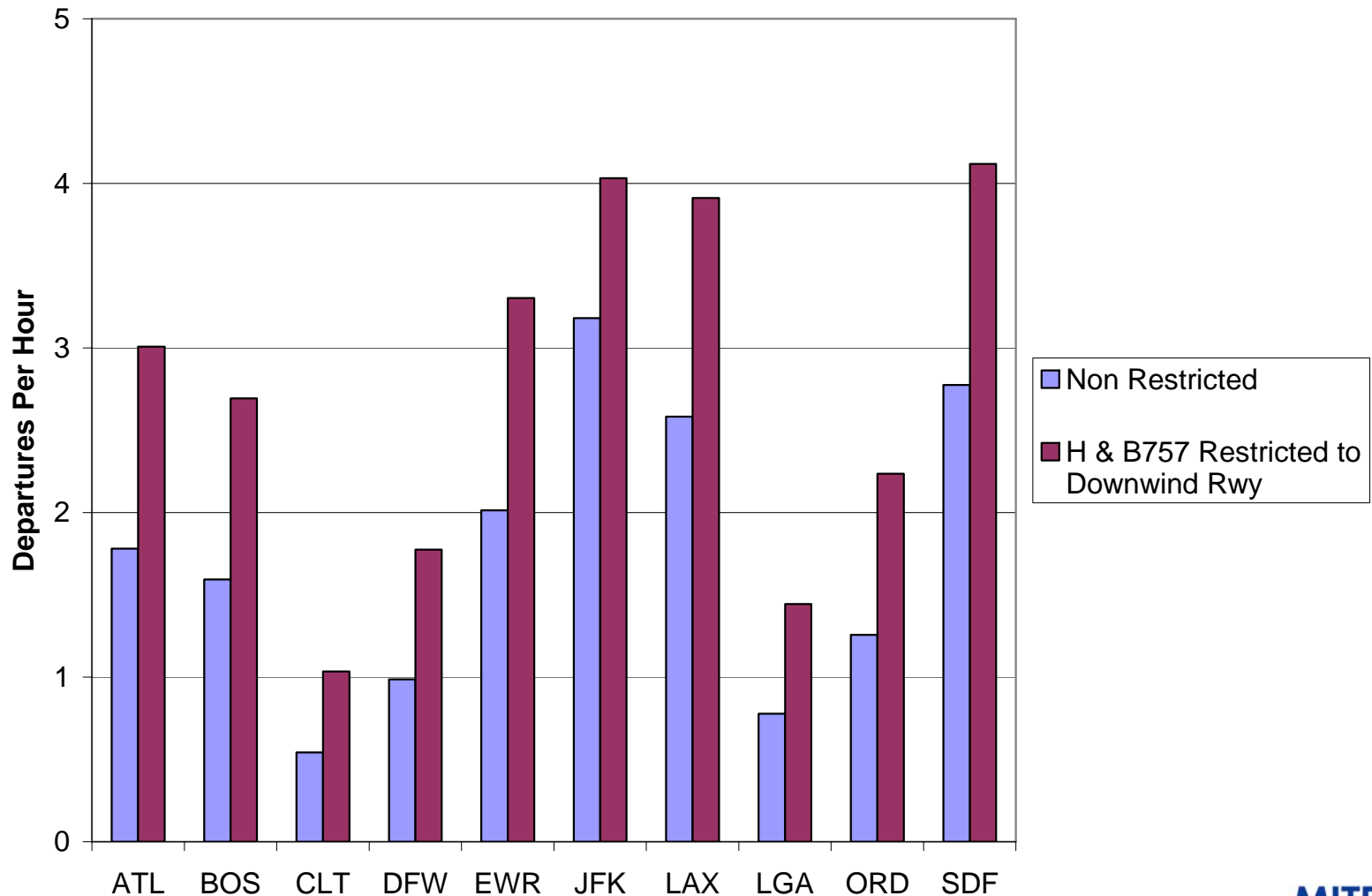


CSPR Arrival Rate Increase





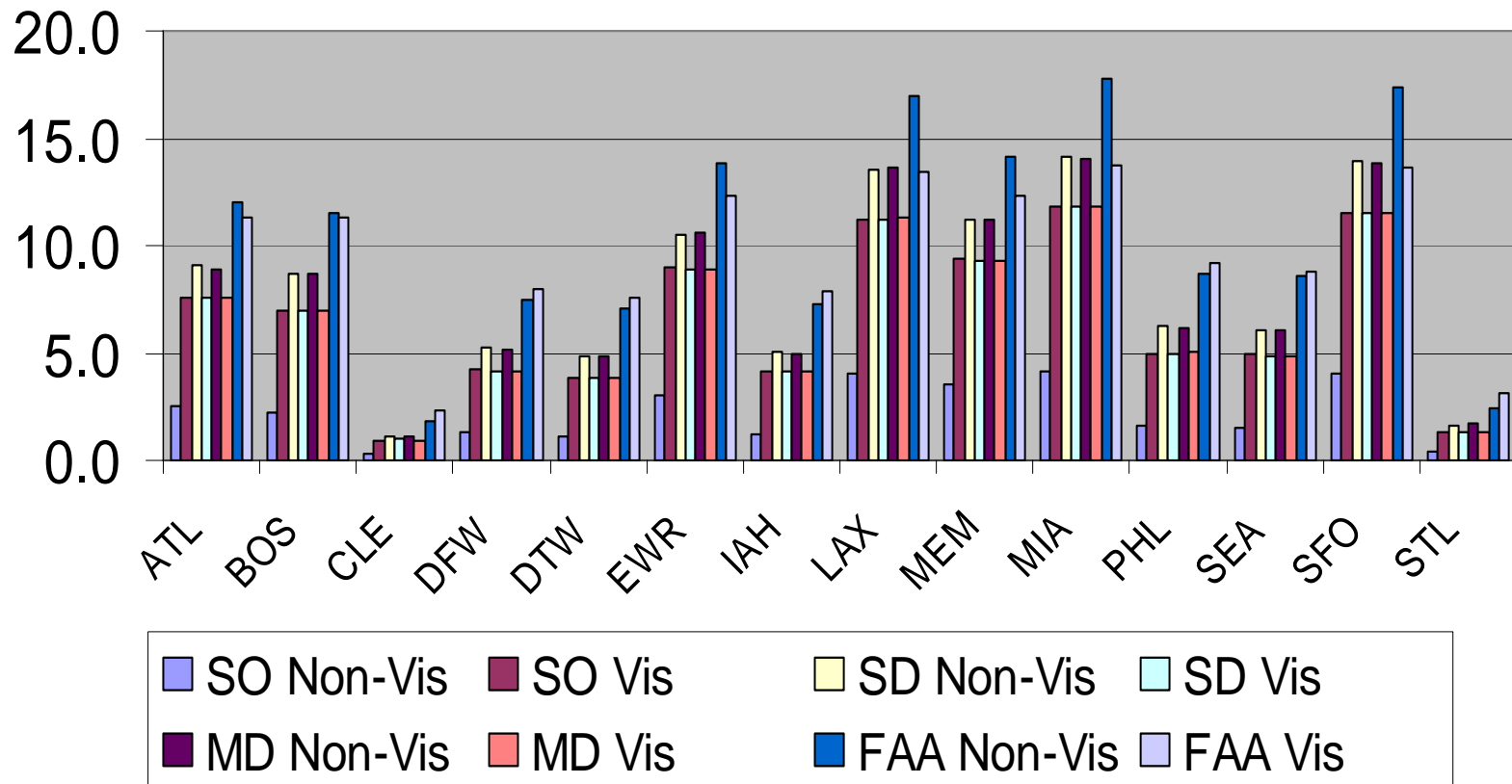
Single Runway Departure Increases (Visual, Dual Dept Path)





CSPR Departure Capacity Increases (Heavy Restricted Downwind)

Comparison of Capacity Increases (Heavy and B757 Restricted to Downwind Runway)



The full benefit possible in unrestricted departure operations may not be realized for normal arrival/departure operations

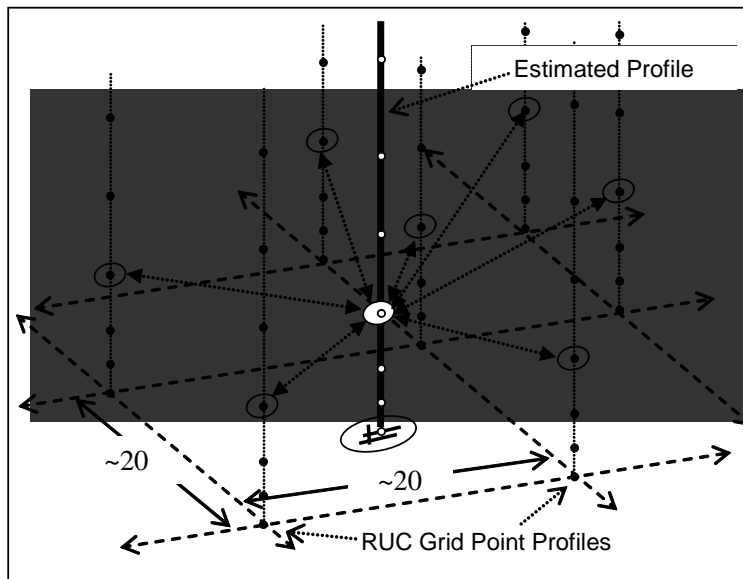


Opportunities to Use Conops



Wind Analysis

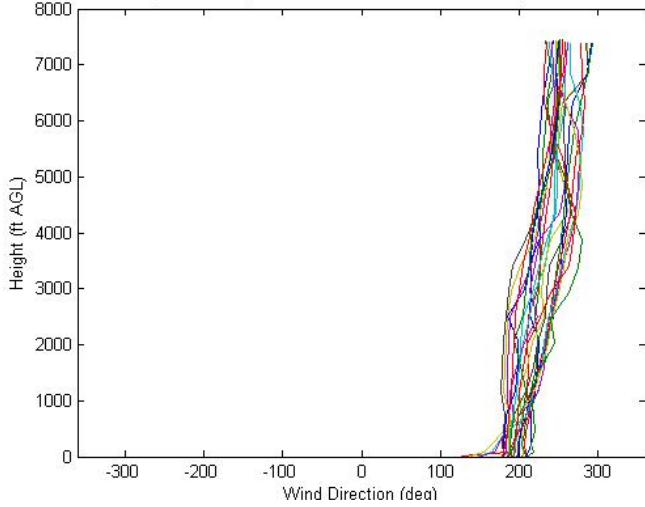
- Reviewed potential wind data sources for benefits analysis and selected RUC
 - 20 km Analysis – assimilates ACARS, NEXRAD, RAWIN, ASOS, wind profiler and previous RUC forecast
 - Analysis accuracy \approx measurement accuracy in terminal area
 - 50 level Native (isentropic) grid with ~17 levels from sfc to 6,000 ft and 5 levels from surface to 1000 ft)



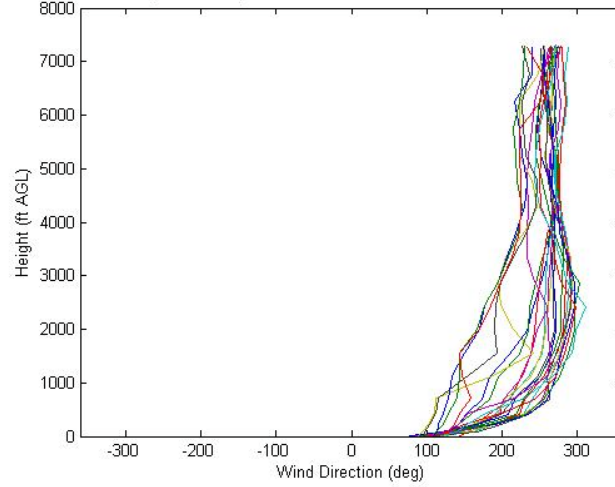


Sample Wind Profiles

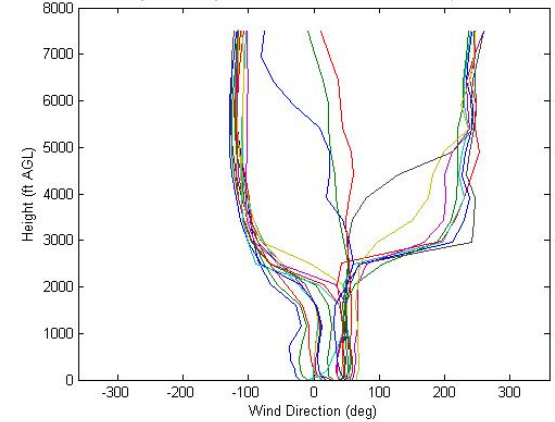
Hourly RUC Analysis Wind Direction Profile for STL Apr 02, 2003



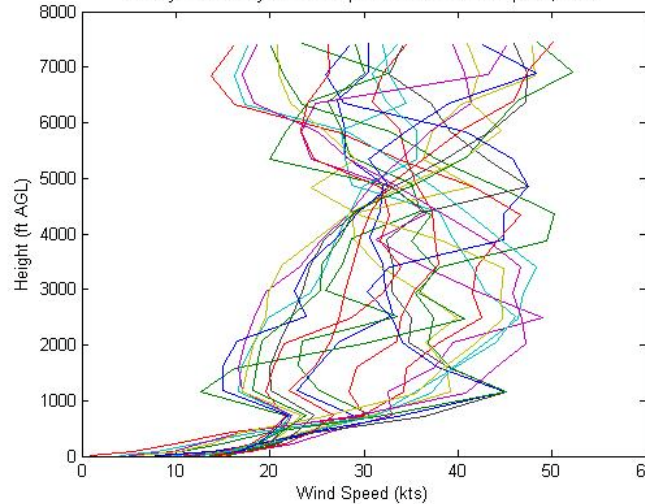
Hourly RUC Analysis Wind Direction Profile for STL Feb 02, 2003



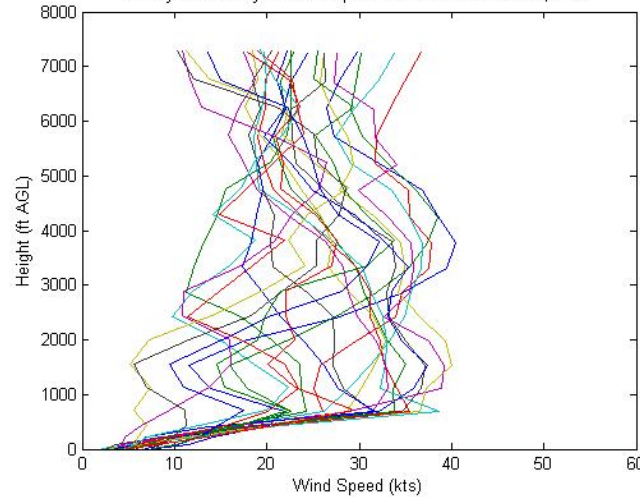
Hourly RUC Analysis Wind Direction Profile for STL Sep 02, 2003



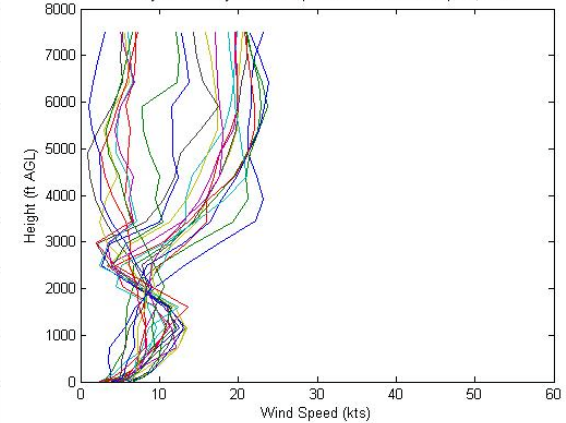
Hourly RUC Analysis Wind Speed Profile for STL Apr 02, 2003



Hourly RUC Analysis Wind Speed Profile for STL Feb 02, 2003

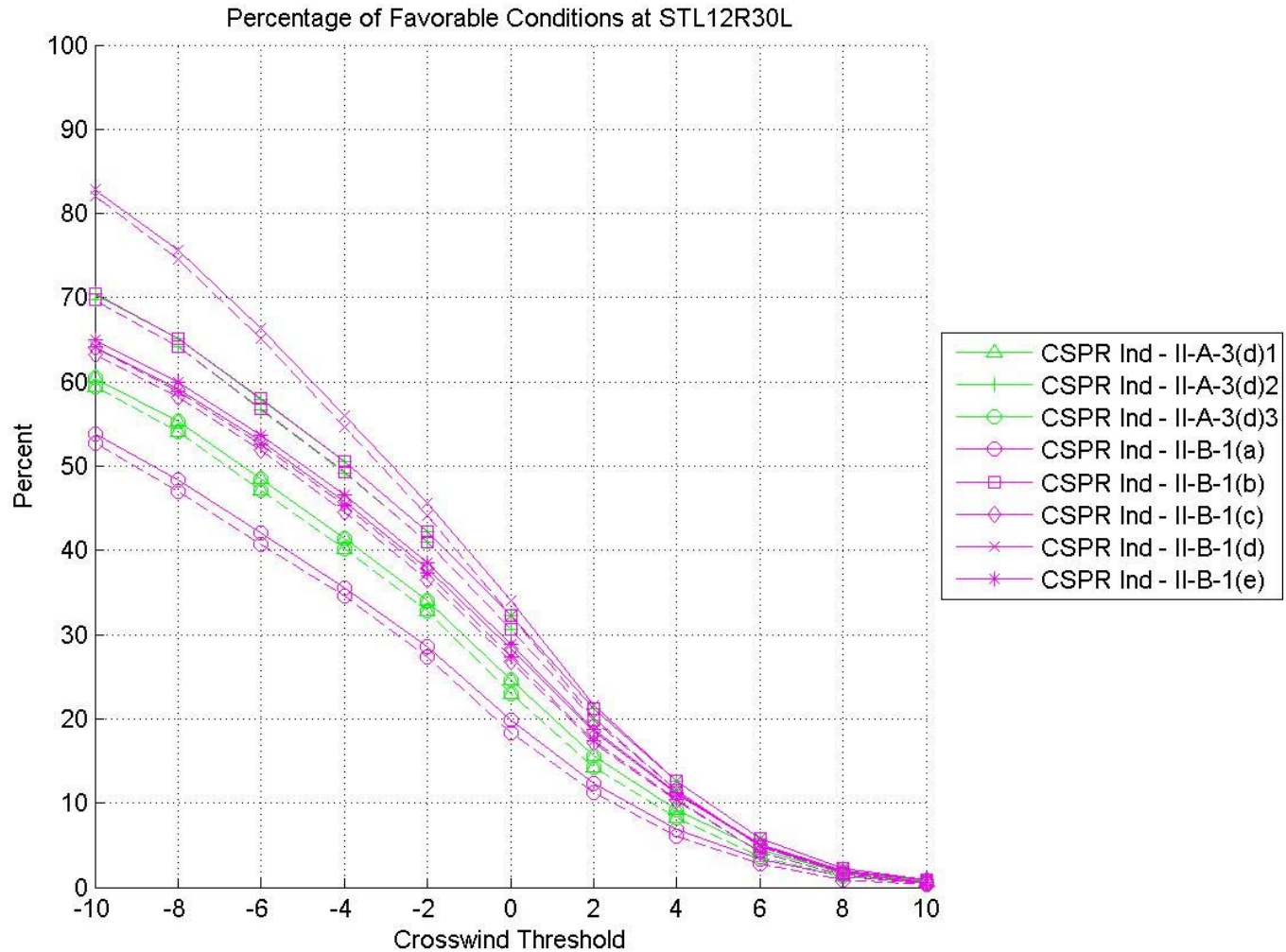


Hourly RUC Analysis Wind Speed Profile for STL Sep 02, 2003



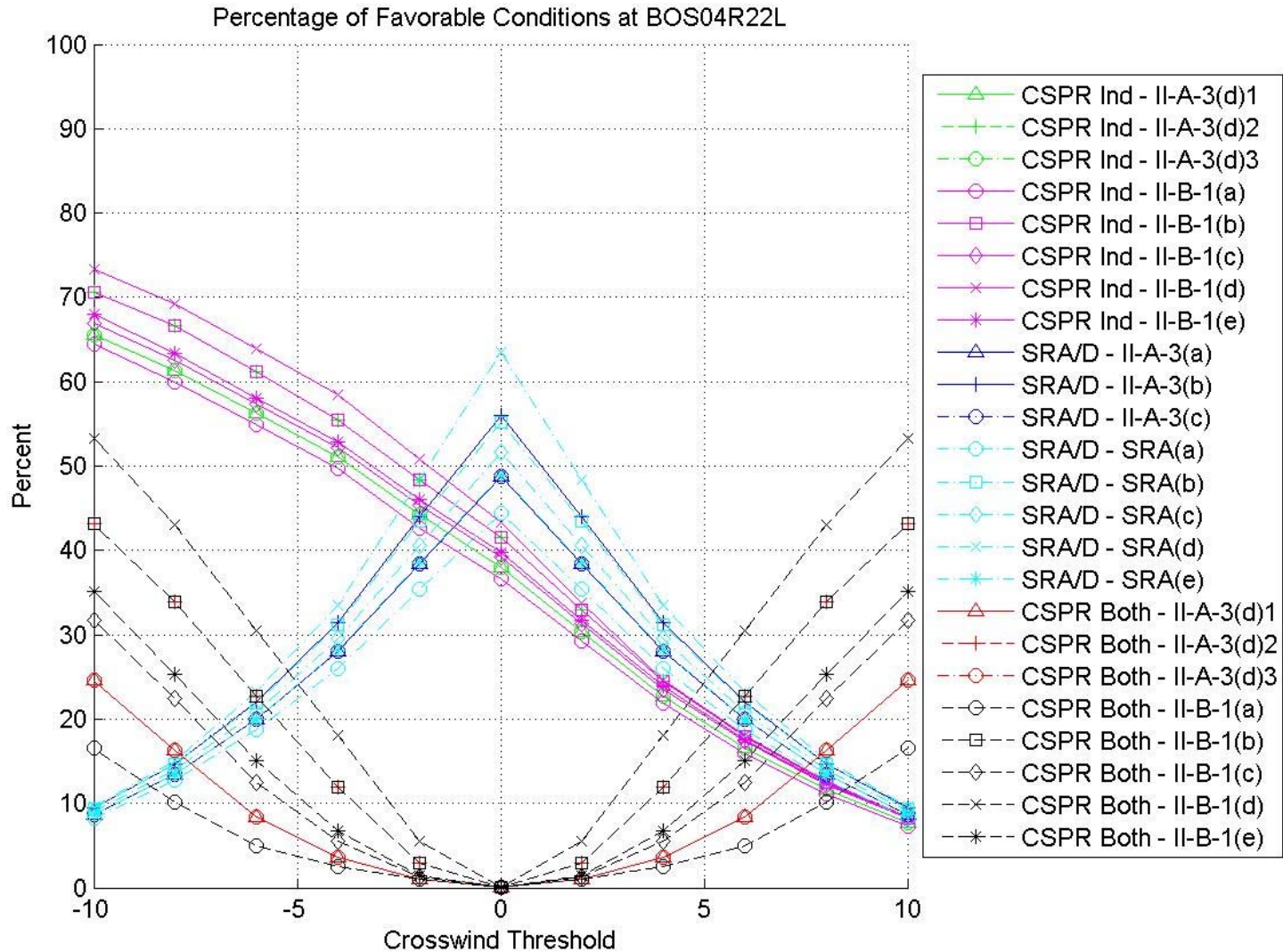


Example of Wind Availability for CSPR Conops





Wind Threshold Availability





Single Runway Conop Availability (With Respect to Winds*)

For 1 Hour Persistence		Single Runway Dept	Single Runway Dept	Single Runway Dept	Single Runway Arrival	Single Runway Arrival	Single Runway Arrival	Single Runway Arrival	Single Runway Arrival
		II-A-3(a)	II-A-3(b)	II-A-3(c)	II-B-2(a)	II-B-2(b)	II-B-2(c)	II-B-2(d)	II-B-2(e)
Airport	Runway Most Available	5 nm Straight-Out	1 nm Single Diverge	5 nm Multi-Diverge	Straight-In	Angled 3 Degree to MAP	Angled 3 Degree to FAF	LDA to MAP	Single 3 Degree to MAP
ATL	08L / 26R	0.9%	6.4%	0.9%	0.8%	4.4%	2.3%	4.5%	4.1%
BOS	04L / 22R	8.6%	22.0%	8.6%	8.2%	18.3%	14.0%	19.2%	16.8%
CLE	10S / 28S	4.7%	20.6%	4.7%	4.0%	16.5%	10.5%	18.0%	12.9%
CLT	05S / 23S	0.4%	3.1%	0.4%	0.4%	2.3%	1.4%	2.3%	2.2%
DFW	18R / 36L	1.9%	8.4%	1.9%	1.9%	6.2%	3.5%	6.5%	4.9%
EWR	04L / 22R	6.5%	17.0%	6.5%	6.3%	13.8%	10.5%	14.2%	13.3%
JFK	04R / 22L	9.1%	21.7%	9.1%	8.8%	18.1%	14.2%	18.8%	16.8%
LAX	07R / 25L	0.1%	1.0%	0.1%	0.1%	0.7%	0.4%	0.7%	0.6%
LGA	04S / 22S	6.8%	17.0%	6.8%	6.6%	14.2%	11.0%	14.5%	13.3%
ORD	14R / 32L	5.3%	24.6%	5.3%	4.9%	18.7%	11.9%	19.6%	16.2%
PHL	17S / 35S	3.2%	13.4%	3.2%	2.8%	10.0%	6.4%	10.3%	8.8%
SDF	11S / 29S	2.7%	14.4%	2.7%	2.4%	10.9%	6.9%	11.3%	9.2%
STL	06S / 24S	4.6%	21.0%	4.6%	4.3%	16.1%	10.7%	16.9%	14.1%

* Does not take into consideration ceiling and visibility, or traffic demand



Conop Availability for CSPR Pair (With Respect to Winds*)

For 1 Hour Persistence		CSPR	CSPR	CSPR	CSPR	CSPR	CSPR	CSPR	CSPR
		Dept	Dept	Dept	Arrival	Arrival	Arrival	Arrival	Arrival
		II-A-3(d)1	II-A-3(d)2	II-A-3(d)3	II-B-1(a)	II-B-1(b)	II-B-1(c)	II-B-1(d)	II-B-1(e)
		5 nm Diverge	1 nm Diverge	5 nm Multi-Diverge	Straight-In	Angled 3 Degree to MAP	Angled 3 Degree to FAF	LDA to MAP	Single 3 Degree to MAP
BOS	04L/R	56.6 %	77.3%	56.6%	40.5%	78.1%	75.1%	78.7%	76.1%
CLE	06L/R	35.8%	70.8%	35.8%	20.8%	71.5%	63.9%	74.4%	64.0%
DTW	03L/R or 04L/R	70.7%	78.6%	70.7%	59.0%	78.6%	78.5%	78.6%	78.6%
DTW	09L/R	70.3%	78.6%	70.3%	57.3%	78.6%	78.6%	78.7%	78.6%
MEM	18C/L	29.9%	78.3%	29.9%	NA	NA	NA	NA	NA
MIA	08L/R	24.1%	61.6%	24.1%	NA	NA	NA	NA	NA
PHL	09L/R	26.2%	77.7%	26.2%	30.4%	78.4%	75.7%	79.2%	77.0%
SEA	16L/R	10.1%	39.0%	10.1%	0.1%	51.6%	44.4%	60.4%	44.1%
SFO	01L/R	21.1%	57.7%	21.1%	6.6%	57.7%	50.6%	67.0%	50.3%
SFO	10L/R	7.3%	38.6%	7.3%	2.0%	38.6%	29.5%	54.3%	29.4%
STL	12L/R	49.2%	91.3%	49.2%	33.7%	93.8%	90.7%	94.5%	91.3%

* Does not take into consideration ceiling and visibility, or traffic demand



Conop Ranking Considerations



Conop Ranking Considerations

WakeVAS Phase II COEs/Conops		Aircraft/Airport/WX/Traffic Mix Characteristics Where WakeVAS Conops Would Provide Most Benefit	Likelihood of Successfully Resolving Research Questions/ Cost of Addressing Research Questions								Hazard Assessment
			WX & Wake Behavior	Wake VAS Systems	CNS/ATM Systems			ATC Operations	Flight Operations	Safety Analysis	
					C	N	S				
Single Runway Arrivals	Straight-in	Stronger crosswinds, High percentage Heavy/757, Frequent IMC	2/2 A	2/2 G	1 / 1	1/ 1	1/ 1	1/1	1/2	1/1	Less difficult issues than departures
	Alt. Angled	Stronger crosswinds, High percentage Heavy/757, Frequent IMC	1.5/1.5 A	2/2 G,H	1 / 1	2/ 2	2/ 2	2/2 H	2/2 D	1/1 F	Less difficult issues than departures
CSPR Arrivals		Weaker crosswinds, High percent Heavy/757, Low Rwy Spacing, Frequent IMC	1/2 A	1/1 G	1 / 1	2/ 2	2/ 2	1/2 E	2/2 D	1/1 F	Less difficult issues than departures
Single Runway Departures		Stronger crosswinds, High percentage Heavy/757	2/2 A	2/2	1 / 1	3/ 3	2/ 2	1/2	2/2	2/2	More difficult issues than arrivals
CSPR Departures**		Weaker crosswinds High percentage Heavy/757, Low Runway Spacing	1/2 A	1/1	1 / 1	1/ 1 C	1/ 1 B	1/2	2/2	2/2	More difficult issues than arrivals

these ratings are differentiators only; built on top of common issues as addressed by the CET





Conop Ranking Considerations

WakeVAS Phase II COEs/ Conops	Aircraft/Airport/WX /Traffic Mix Characteristics where WakeVAS Conops would provide most benefit	Benefits			Research		Institutional Issues			
		Pote ntial Capa city Bene fit	Oppor tunity for Use w.r.t winds	Oppor tunity for Use w.r.t. VMC/IMC	Diffic ulty	Co st	Certific ation	Transi tion	Stakeholder Acceptance	
									Hum an Facto rs	Proced ure Comple xity
Single Runway Arrivals	Stronger crosswinds, High percentage Heavy/757, Frequent marginal VMC and IMC	1-3	0-19%	Marginal VMC and IMC	1.5	1.5	1.5	1.5	1	1.5
		(6-8*)			2.0	2.0				
CSPR Arrivals	Weaker crosswinds, Low Rwy Spacing, Frequent marginal VMC and IMC	6-18	0-77%	Marginal VMC and IMC	1	1.5	1	1	1.5	1
Single Runway Departur es	Stronger crosswinds, High percentage Heavy/757; applicable in all visual conditions	1-3	0-25%	All Weather	2.5	2.5	2	1.5	2	2
CSPR Departur es**	Weaker crosswinds High percentage Heavy/757, applicable in all visual conditions	1- 14**	1-78%	All Weather	1	1.5	1.5	1	2	1.5

** CSPR departure rates for runways dedicated to departures.

* 6-8 single runway arrivals for a 2 nmi min behind large aircraft



Additional Information



CET Conop Designations

CET Conops Designation	Description
II-B-2 (a)	Single Runway Arrivals Straight-In
II-B-2 (b)	Single Runway Arrivals Angled 3 Degree Approaches to MAP
II-B-2 (c)	Single Runway Arrivals Angled 3 Degrees to FAF, and Straight-In Final
II-B-2 (d)	Single Runway Arrivals LDA/Glideslope Angled 30 Degrees
II-B-2 (e)	Single Runway Arrivals One Angled/One Straight-In
II-B-1 (a)	CSPR Arrivals Straight-In Parallel
II-B-1 (b)	CSPR Arrivals Angled 3 Degree Approaches
II-B-1 (c)	CSPR Arrivals Angled 3 Degrees to FAF, Straight-In Final
II-B-1 (d)	CSPR Arrivals LDA/Glideslope Angled 30 Degrees
II-B-1 (e)	CSPR Arrivals One Angled/One Straight-In
II-A-3 (a)	Single Runway Departures Straight-Out
II-A-3 (b)	Single Runway Single Divergence Point
II-A-3 (c)	Single Runway Multiple Divergence Points
II-A-3 (d) (1)	CSPR Departures Common Path: Straight Out
II-A-3 (d) (2)	CSPR Departures Single Diverge at 1 nmi: Straight One Side
II-A-3 (d) (3)	CSPR Departures Multiple Diverge: Straight One Side



Evaluate Conop Geometries

- **Determine Alternate Separation Zone heights and crosswind wake transport allowed (or required)**
- **Model wake transport (used APA 3.2), adjusting IGE transport, for range of crosswinds and EDRs**
- **Calculate airport, Conop, and height specific crosswind requirements**

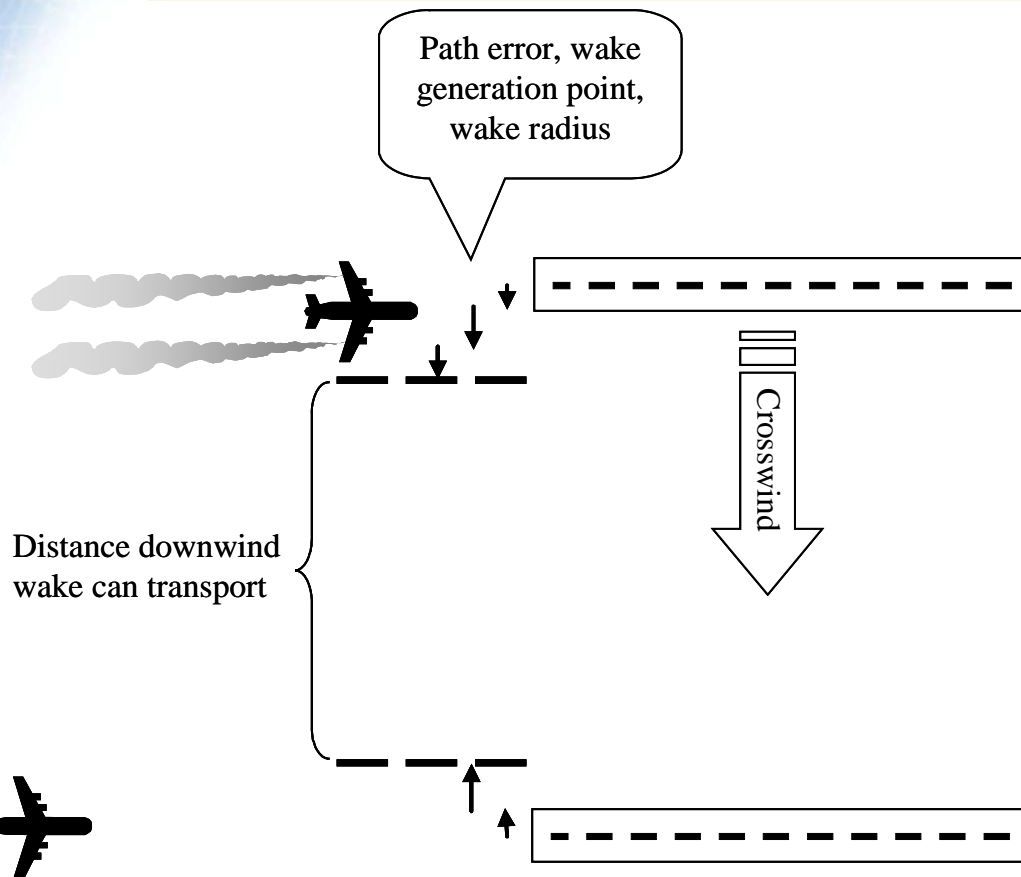


Alternate Separation Zone Heights (feet)

	CSPR	CSPR	CSPR	CSPR	CSPR	CSPR	CSPR	CSPR
AirportRwy	II-A-3(d)1	II-A-3(d)2	II-A-3(d)3	II-B-1(a)	II-B-1(b)	II-B-1(c)	II-B-1(d)	II-B-1(e)
ATL	3569	1169	3569	N/A	N/A	N/A	N/A	N/A
BOS	3393	993	3393	6000	841	2091	281	1708
CLE	3494	1094	3494	6000	994	2244	288	2085
DFW	3510	1110	3510	N/A	N/A	N/A	N/A	N/A
DTW	3196	796	3196	6000	546	1796	265	979
EWR	3628	1228	3628	6000	1196	2446	299	2582
IAH	3589	1189	3589	N/A	N/A	N/A	N/A	N/A
LAX	3707	1307	3707	6000	1314	2564	305	2874
MEM	3618	1218	3618	N/A	N/A	N/A	N/A	N/A
MIA	3667	1267	3667	N/A	N/A	N/A	N/A	N/A
PHL	3432	1032	3432	6000	900	2150	284	1853
SEA	3667	1267	3667	6000	1255	2505	302	2728
SFO	3687	1287	3687	6000	1284	2534	303	2801
STL	3471	1071	3471	6000	959	2209	287	1999



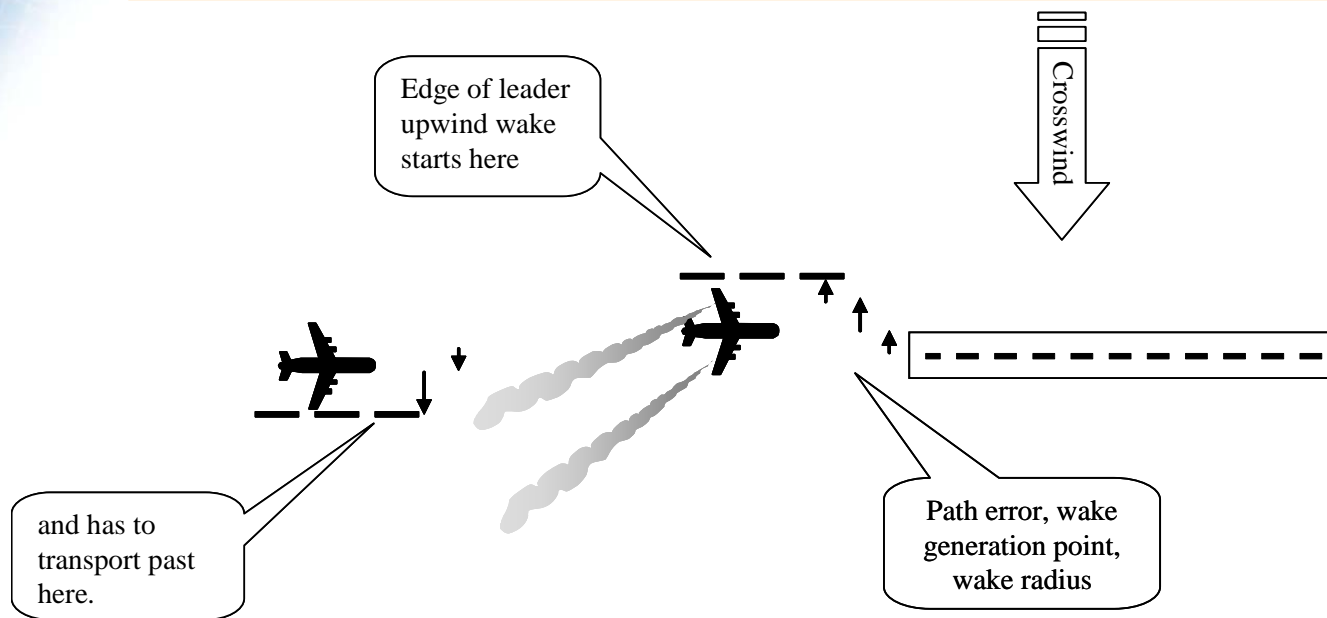
Wind Threshold Calculation for CSPR



Airport	II B 1(a)	II B 1(b)	II B 1(c)	II B 1(d)	II B 1(e)
BOS	1	-5	-5	-5	-5
CLE	3	-3	-3	-3	-3
DTW	-3	-9	-9	-9	-9
EWR	6	-1	-1	-1	-1
LAX	9	0	0	0	0
PHL	1	-5	-5	-5	-5
SEA	8	-1	-1	-1	-1
SFO	8	0	0	0	0
STL	2	-4	-4	-4	-4



Wind Thresholds Calculation for Single Runways



Concept	Where (nmi out from runway)			Minimum Required Crosswind (kts)
	0.5	5	20	
SRA(a)			16	16
SRA(b)	7			7
SRA(c)		8		8
SRA(d)	7			7
SRA(e)	7			7



CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT

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