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Partnership for AiR Transportation Noise and Emission Reduction

An FAA/NASA/TC-sponsored Center of Excellence

Reducing Surface Emissions Through Airport Traffic Optimization

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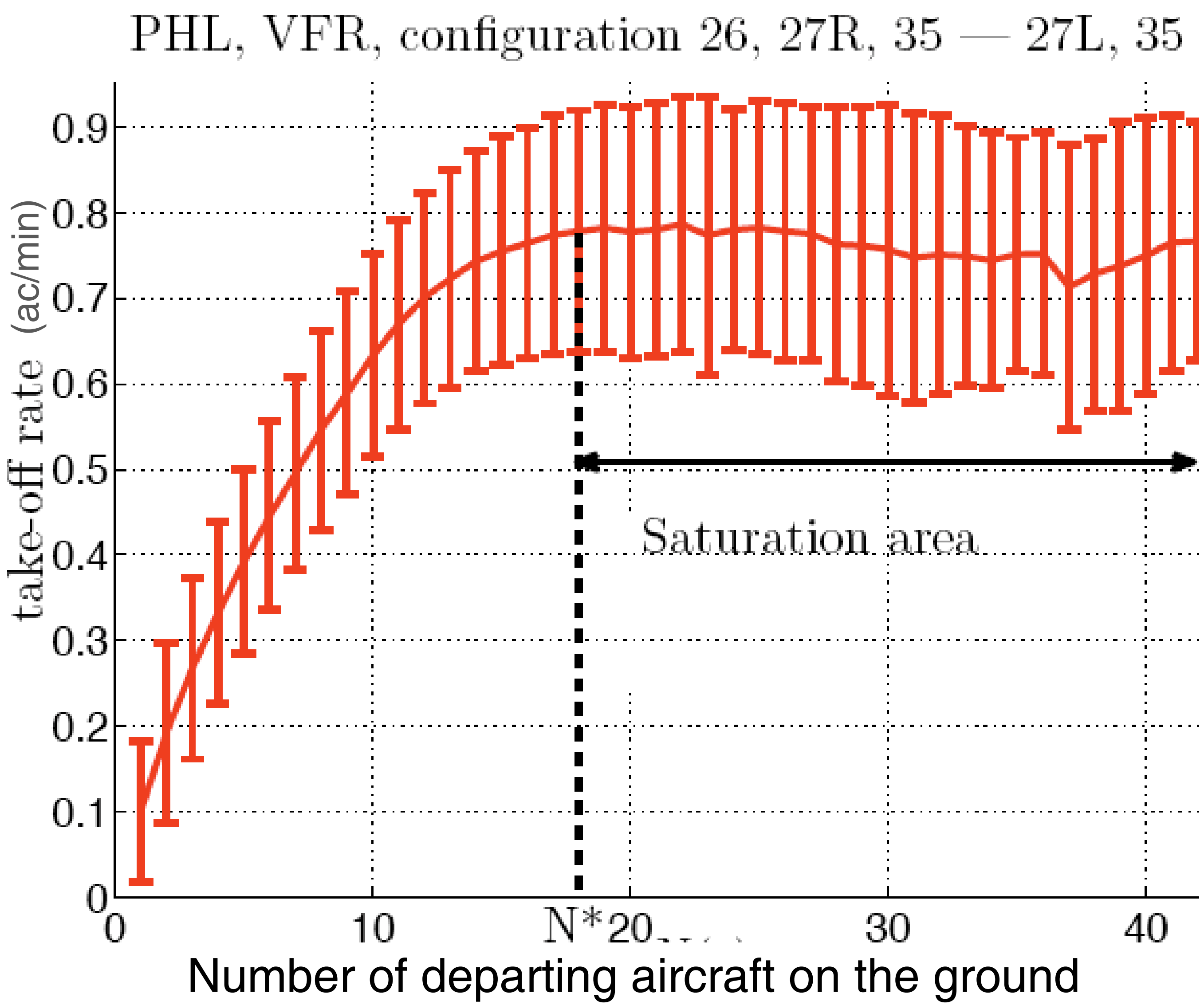
Motivation

- In 2007, aircraft in the U.S. spent over 63 million minutes taxiing in to their gates, and over 150 million minutes taxiing out for departure [FAA ASPM data]

Year	Number of flights with taxi-out time						
	< 20 min	20-39 min	40-59 min	60-89 min	90-119 min	120-179 min	≥ 180 min
2006	6.9 mil	1.7 mil	197,167	49,116	12,540	5,884	1,198
2007	6.8 mil	1.8 mil	235,197	60,587	15,071	7,171	1,565

- Taxiing aircraft burn fuel, and contribute to surface emissions of CO_2, hydrocarbons, NOx, SOx and particulate matter
- In Europe, aircraft are estimated to spend 10-30% of their time taxiing [Airbus]
- A short/medium range A320 expends as much as 5-10% of its fuel on the ground [Airbus]

Departure throughput saturation at airports



Surface congestion results in an increase in taxi times

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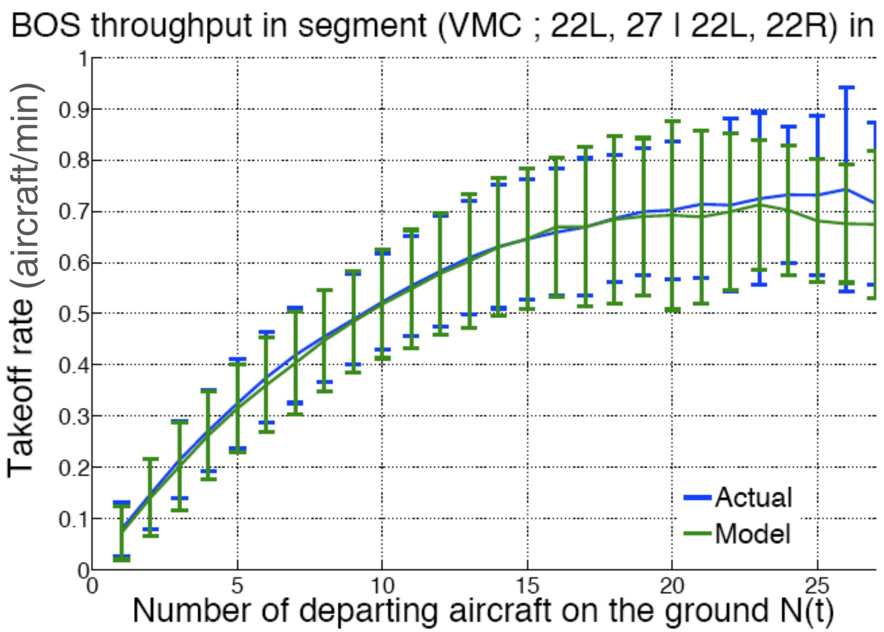
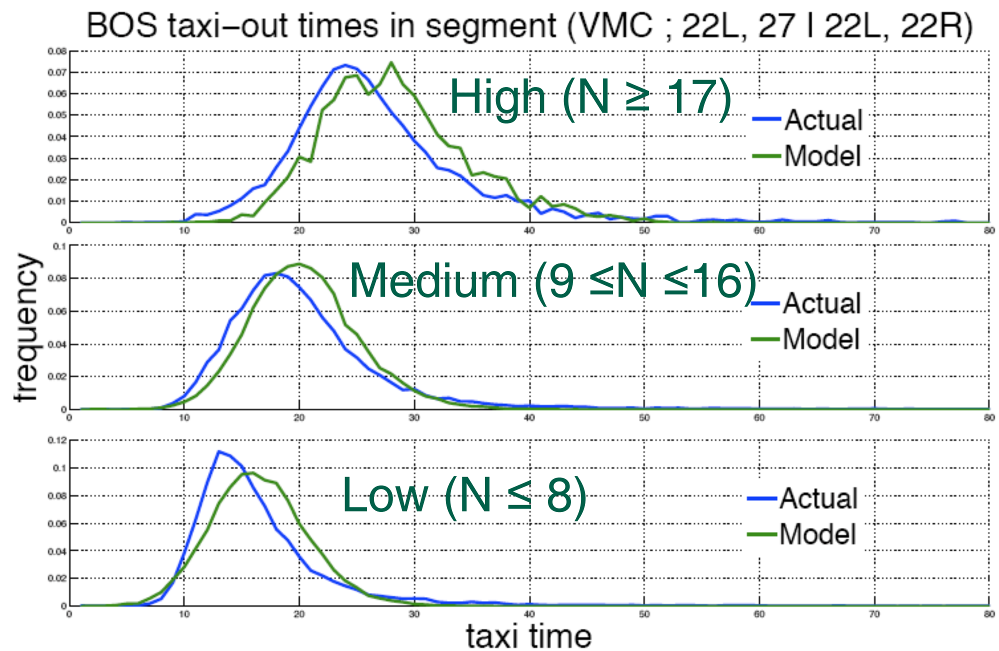


Departure throughput as a function of number of departures on the surface



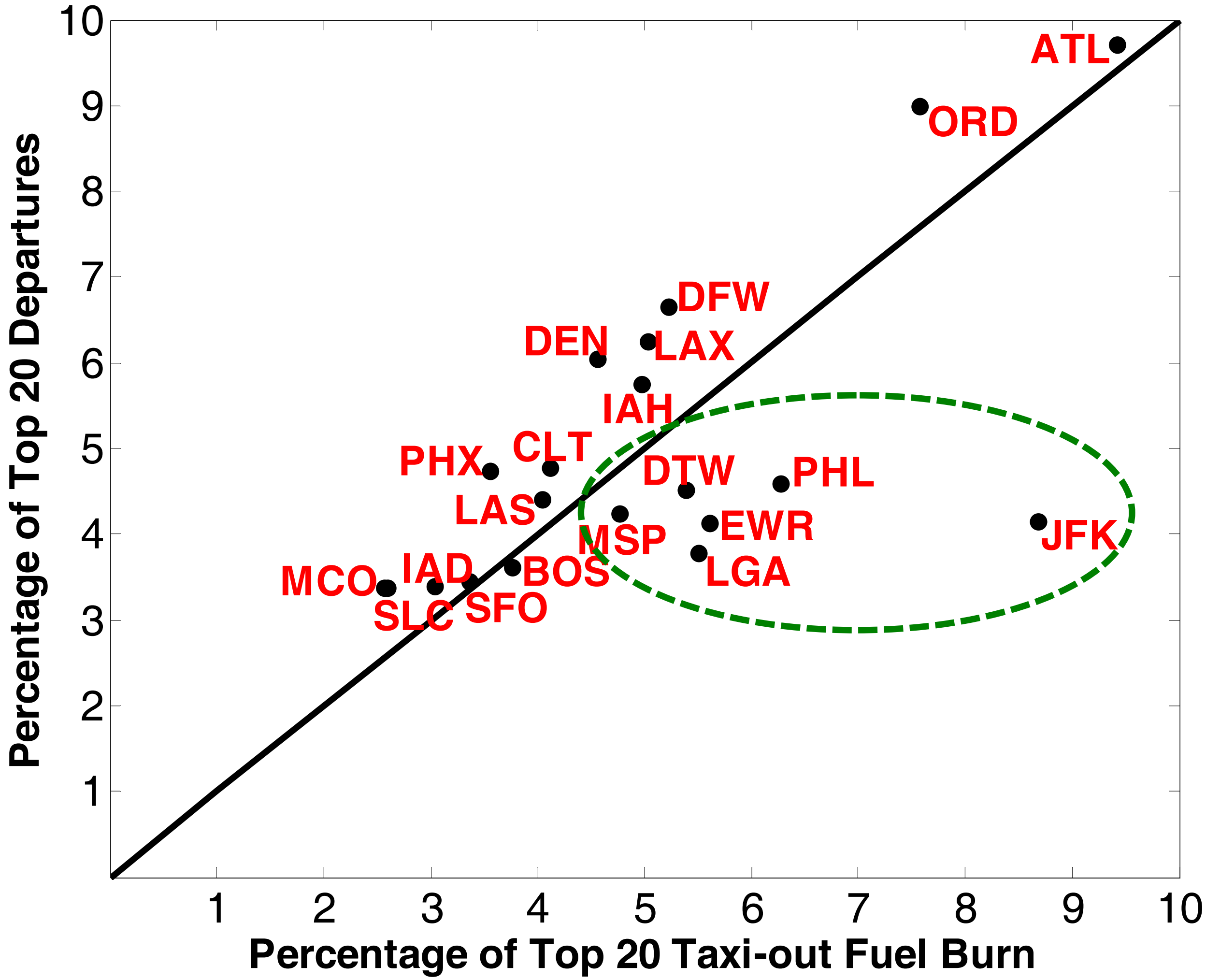
Taxi-out time distributions at different traffic levels (for current operations)

(VFR)

Airport	N^*	Total departures	Pushbacks after saturation	Frequency of saturation	E[taxi time] when saturated
JFK	28	180,171	50,712	17.9%	52.7
EWR	25	171,280	30070	12.5%	48.8
PHL	20	204,002	54,756	16.3%	36.0
BOS	18	155,060	14,410	6.8%	29.5

Evaluation of fuel burn and emissions performance of various airports

- Percentage of (domestic) departures from the top 20 airports vs percentage of the taxi-out fuel burn from these flights

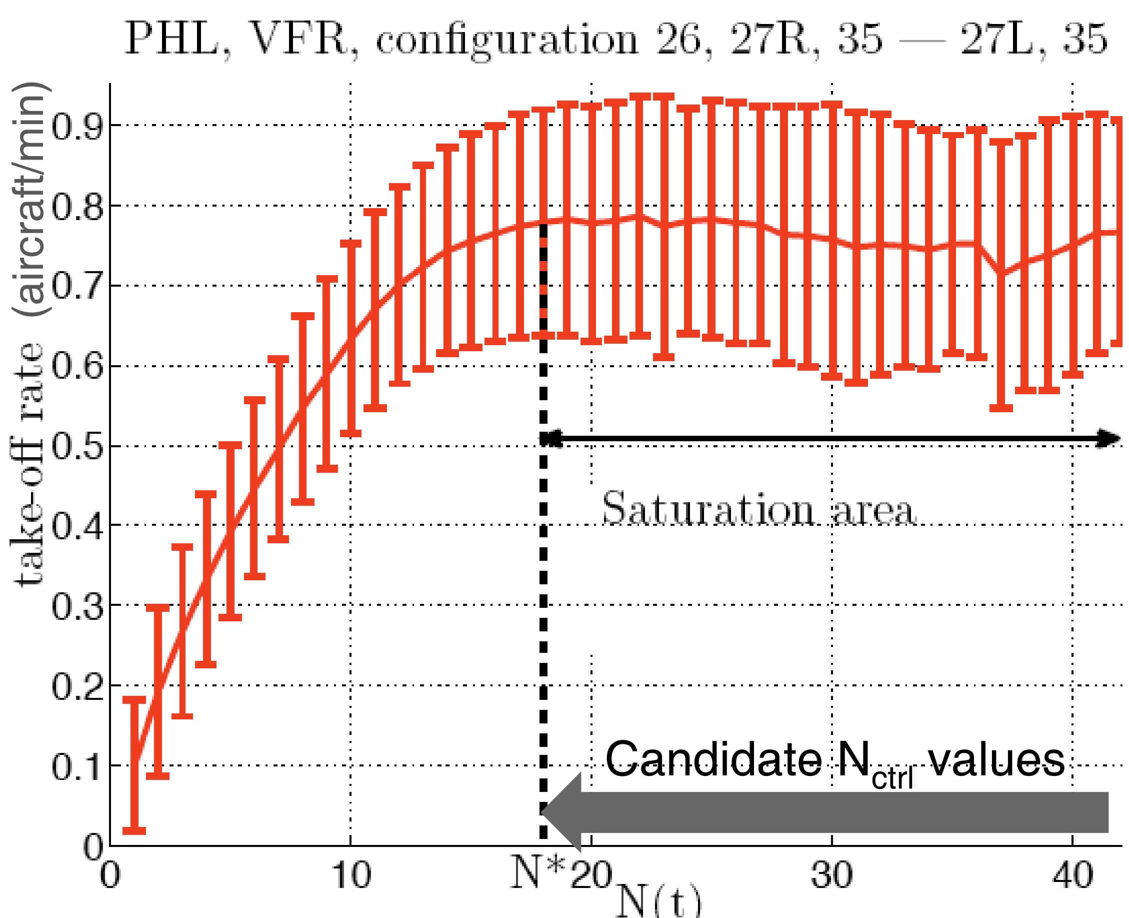


Candidate strategy for evaluation

- Prior studies have highlighted one important ATC strategy: limiting number of aircraft pushing back into the Active Movement Area when surface is already congested
  - Refinement of current approach of controlling pushbacks to within Acceptable Level of Traffic in the movement areas
  - Formalized as N-control strategy
- Demonstrate fuel and environmental benefits of basic N-control strategies
- Evaluate operational and implementation issues associated with N-control

First Phase: Basic N-control

- Conceptually simple: Limit the buildup of queues on the airport surface by controlling the pushback times of aircraft
- Begin with N_{ctrl} >> N*, and decrease gradually



Implementing basic N-control strategies

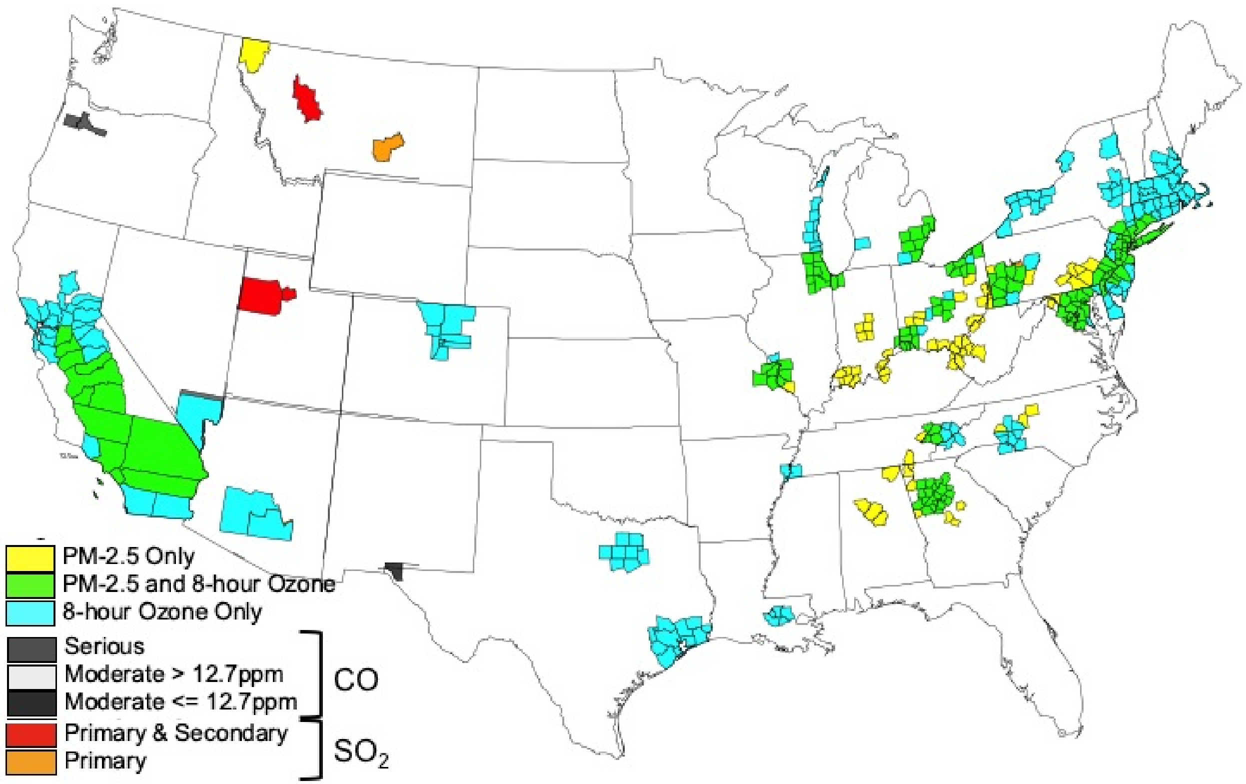
- Begin with $N_{ctrl} >> N^*$, and decrease gradually
  - Carefully monitor for potential system issues, such as, gate use constraints, downstream flow restrictions, taxi times of different airlines, fairness concerns, etc.
  - At high values of N_{ctrl}, we would expect minimal impact on operations (gate use conflicts, etc.)
  - Expect to taxi time/fuel burn/emissions benefits even at higher values of N_{ctrl}
  - As constraints emerge, work with stakeholders to determine if modified procedures can resolve issues and allow further reduction of N_{ctrl}

Benefits of N-control strategy

- Simplicity of concept
- Minimal additional automation/infrastructure/procedural modification requirements
- Can use this as a way to diagnose system dynamics (system identification)
- Identify initial indicators of problems (for example, gate use conflicts)
- Refinement of airport simulation models to reflect taxiway layouts, paths and procedures

Criteria for identifying candidate airports

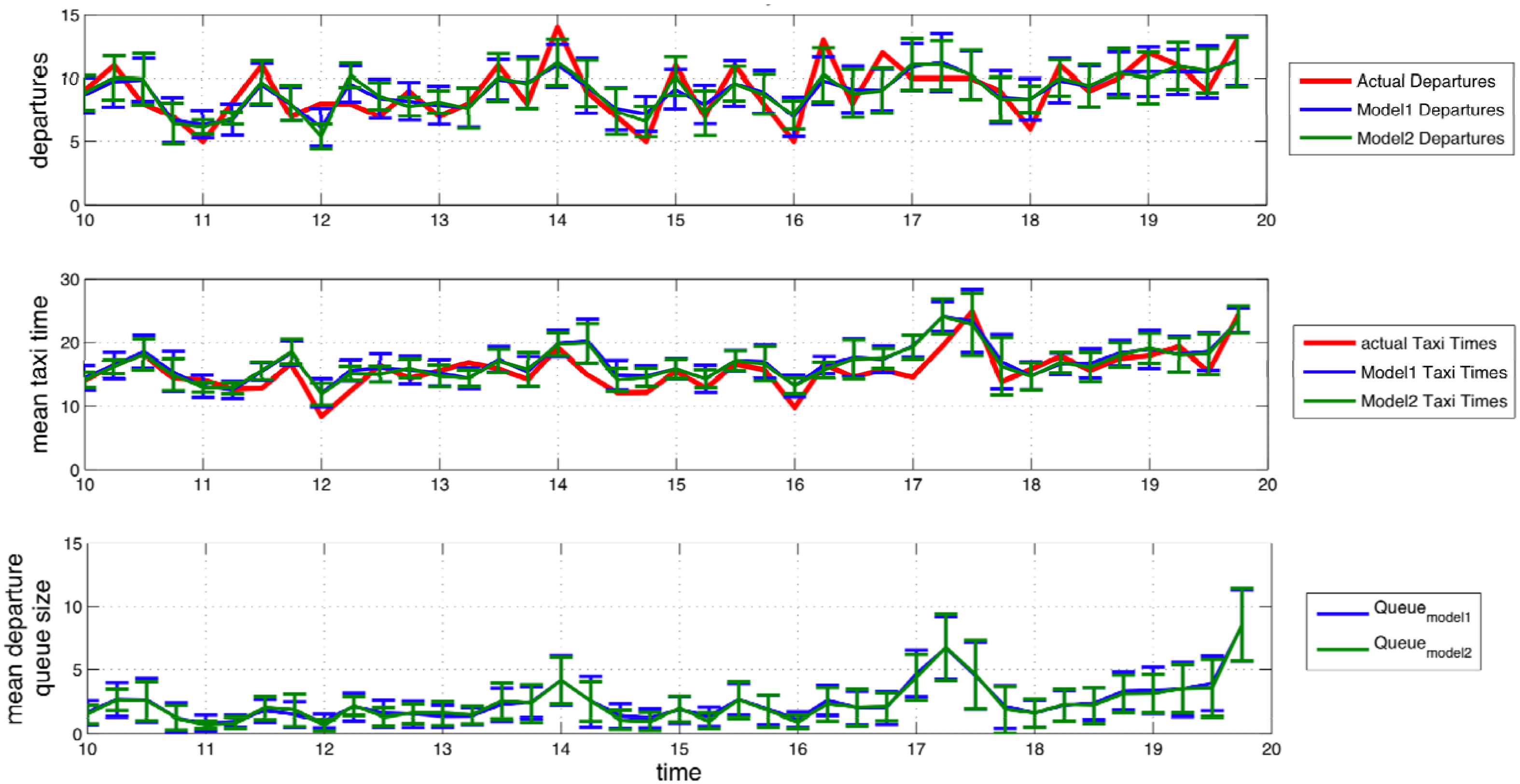
- Significant congestion – Taxi times and taxi delays
- Non-attainment areas



- Availability of surface surveillance/ operational data (ASDE-X)
- Cooperation from: Tower, Airport, Carriers
- Avoid single carrier dominance

Queuing network model of departure processes

- Developed airport model that predicts taxi times and departure queue wait times, given pushback schedules
  - Also proposed method for estimating unimpeded taxi times

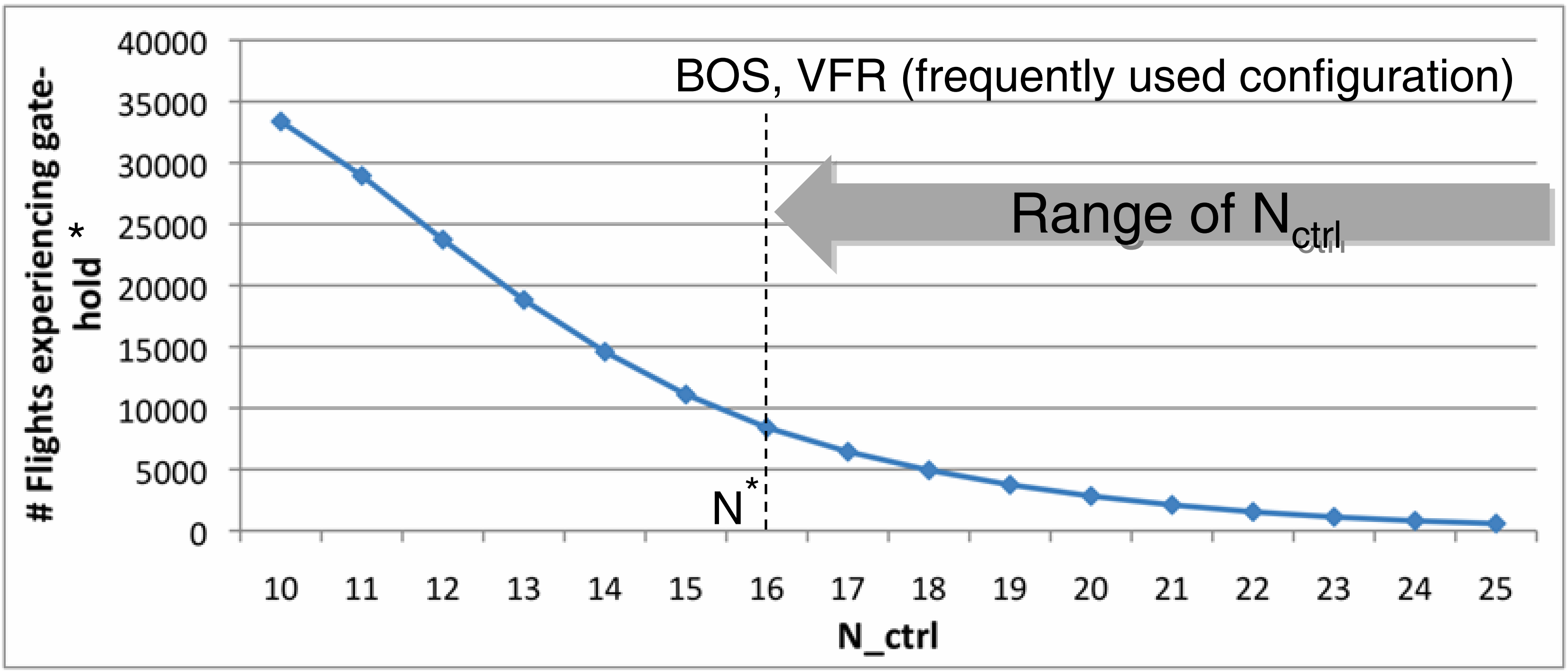


  - Model can be used to evaluate baseline emissions as well as the benefits of queue management strategies

[Simaiakis and Balakrishnan, 2009]

Expected impact of basic N-control strategies

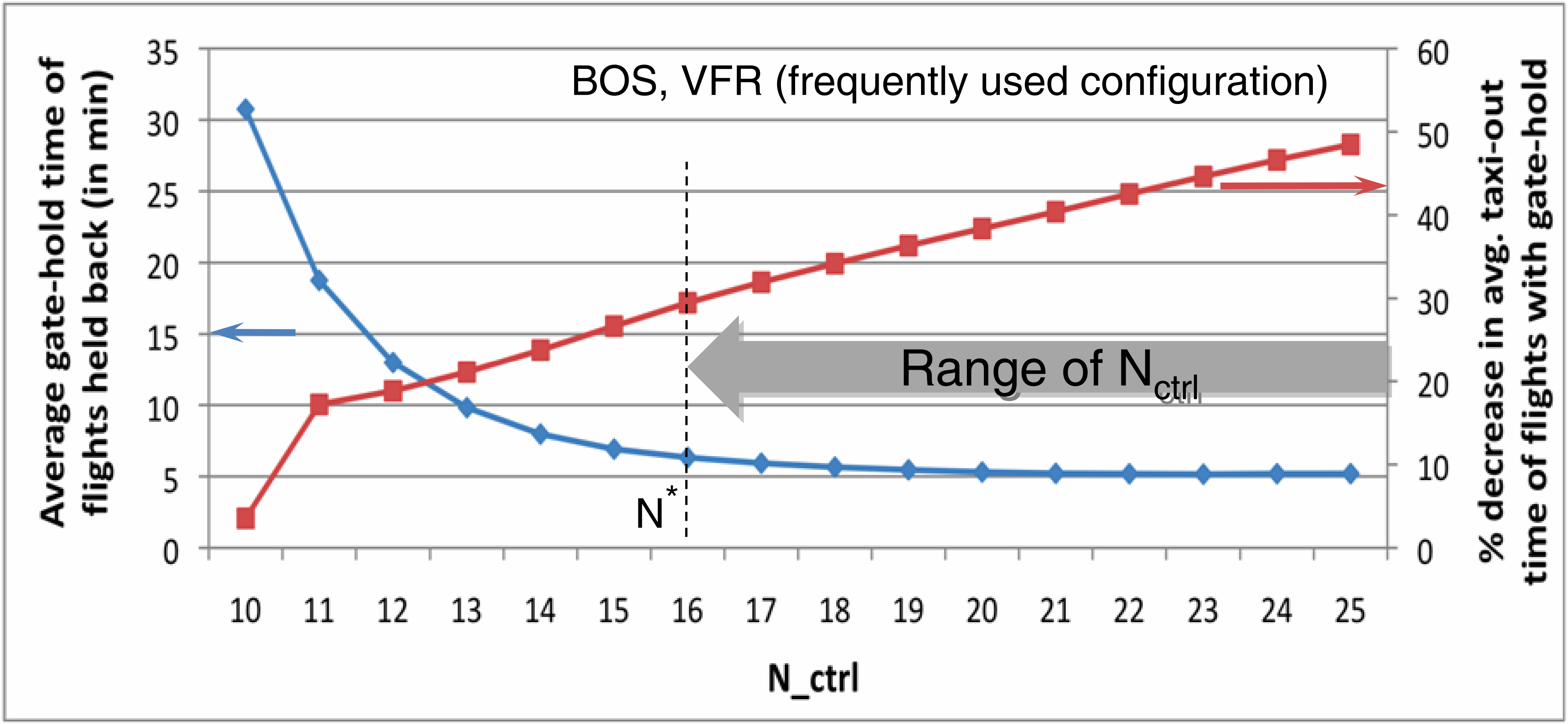
- Need periods of congestion at the airport in order to be beneficial
  - Starting at large values of N_{ctrl} keeps protocol relatively low-risk
  - At larger values of N_{ctrl}, fewer flights experience gate-hold



*values over the course of a year; ~40000 flights departed in VFR under this configuration at BOS in 2007

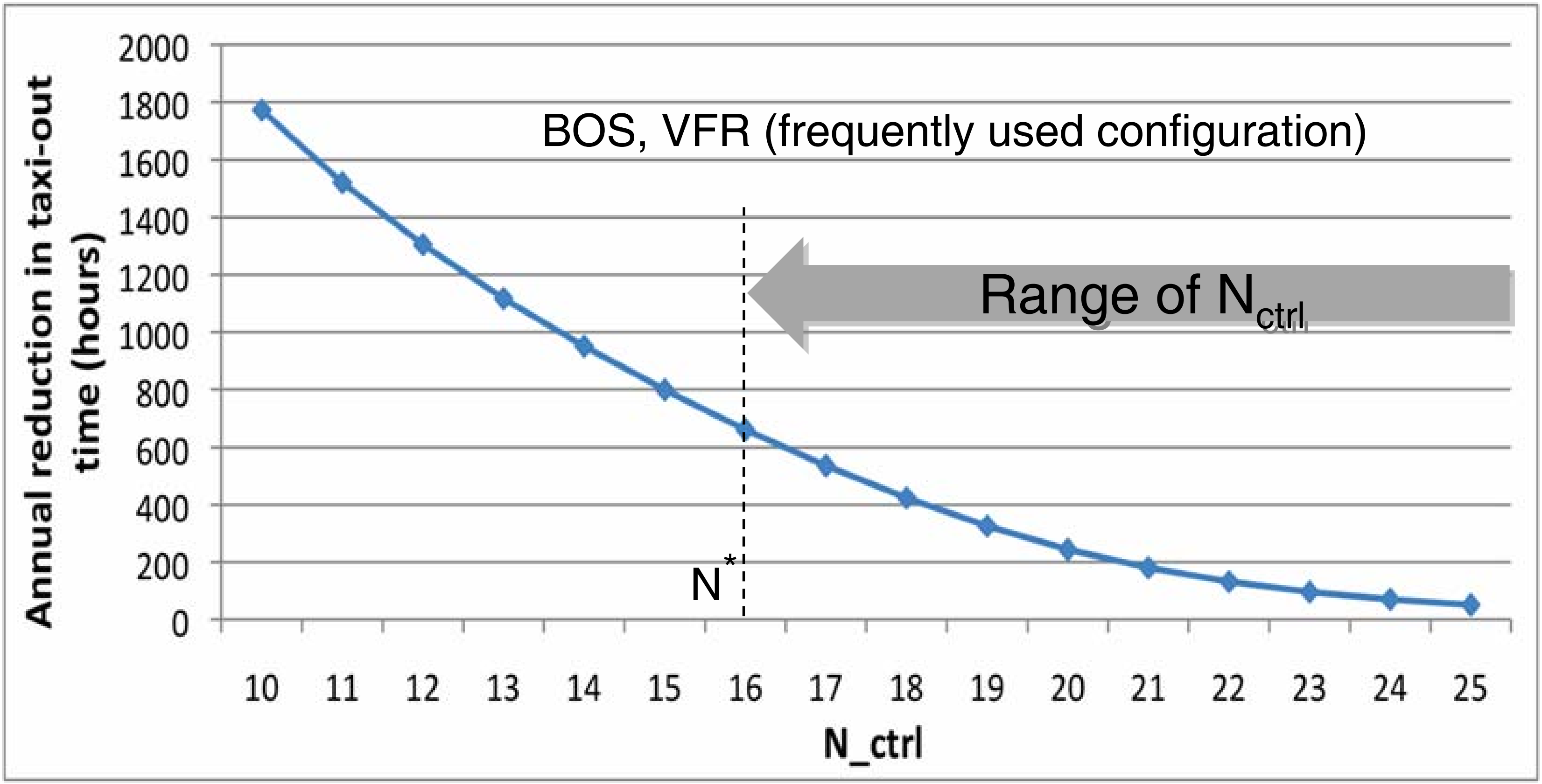
Expected impact of basic N-control strategies

- Higher N_{ctrl} gets impacts fewer flights, but they benefit from a greater decrease in taxi-out times



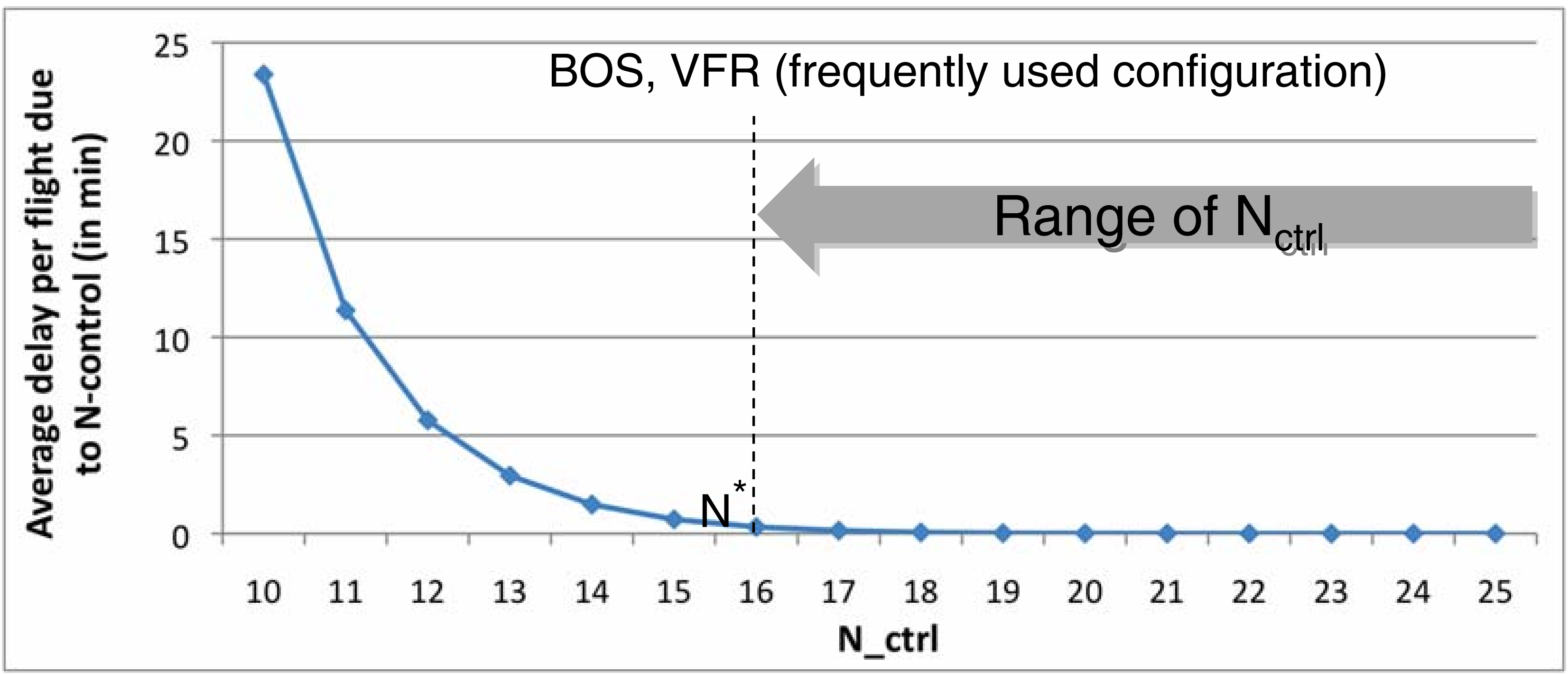
Expected impact of basic N-control strategies

- Total impact increases as N_{ctrl} decreases due to more flights getting taxi time decreases



Expected impact of basic N-control strategies

- Airport throughput is not impacted
- Minimal impact on departure delay (wheels-off time under N-control minus wheels-off time in uncontrolled case)



Potential benefits of N-control strategies: Fuel burn and emissions reduction

22L, 27 | 22L, 22R; VMC [Annual reduction in fuel burn and emissions]

N_{ctrl}	10	15	16	17	18	19	20	21	22
Fuel burn (gallons)	421,308	178,066	146,445	117,811	93,148	71,880	53,933	39,817	29,317
HC (kg)	2,766	1,193	988	801	637	496	376	280	208
CO (kg)	29,412	12,563	10,385	8,397	6,667	5,172	3,907	2,897	2,143
NOx (kg)	5,347	2,258	1,856	1,492	1,179	908	682	503	371

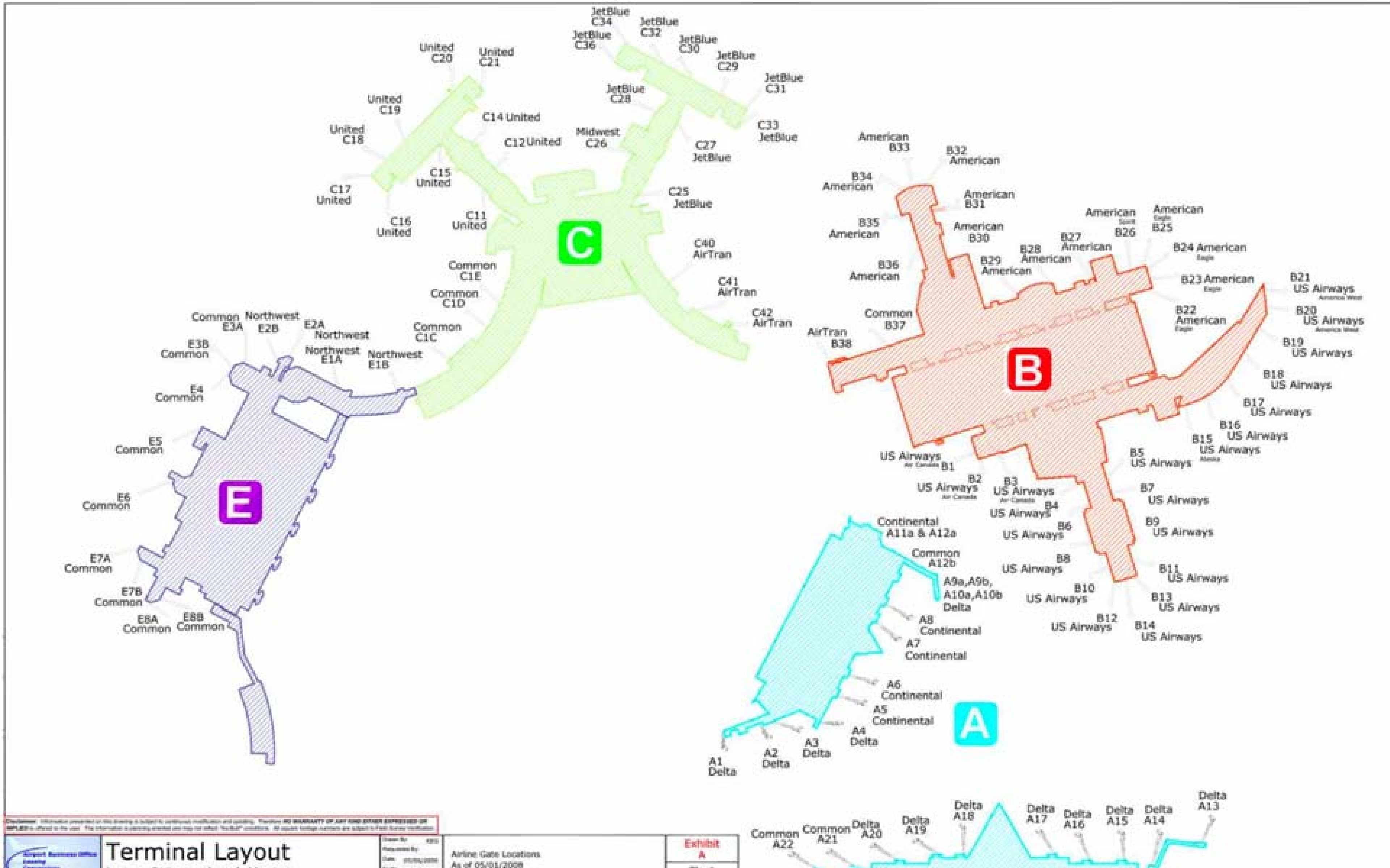
4L, 4R | 4L, 4R, 9; VMC [Annual reduction in fuel burn and emissions]

N_{ctrl}	10	15	16	17	18	19	20	21	22
Fuel burn (gallons)	183,276	57,725	45,468	35,583	27,633	21,526	16,388	12,333	8,986
HC (kg)	1,234	388	310	244	189	149	114	87	64
CO (kg)	12,870	4,150	3,291	2,595	2,020	1,581	1,214	919	680
NOx (kg)	2,319	730	575	450	349	272	207	155	113

27, 32 | 33L; VMC [Annual reduction in fuel burn and emissions]

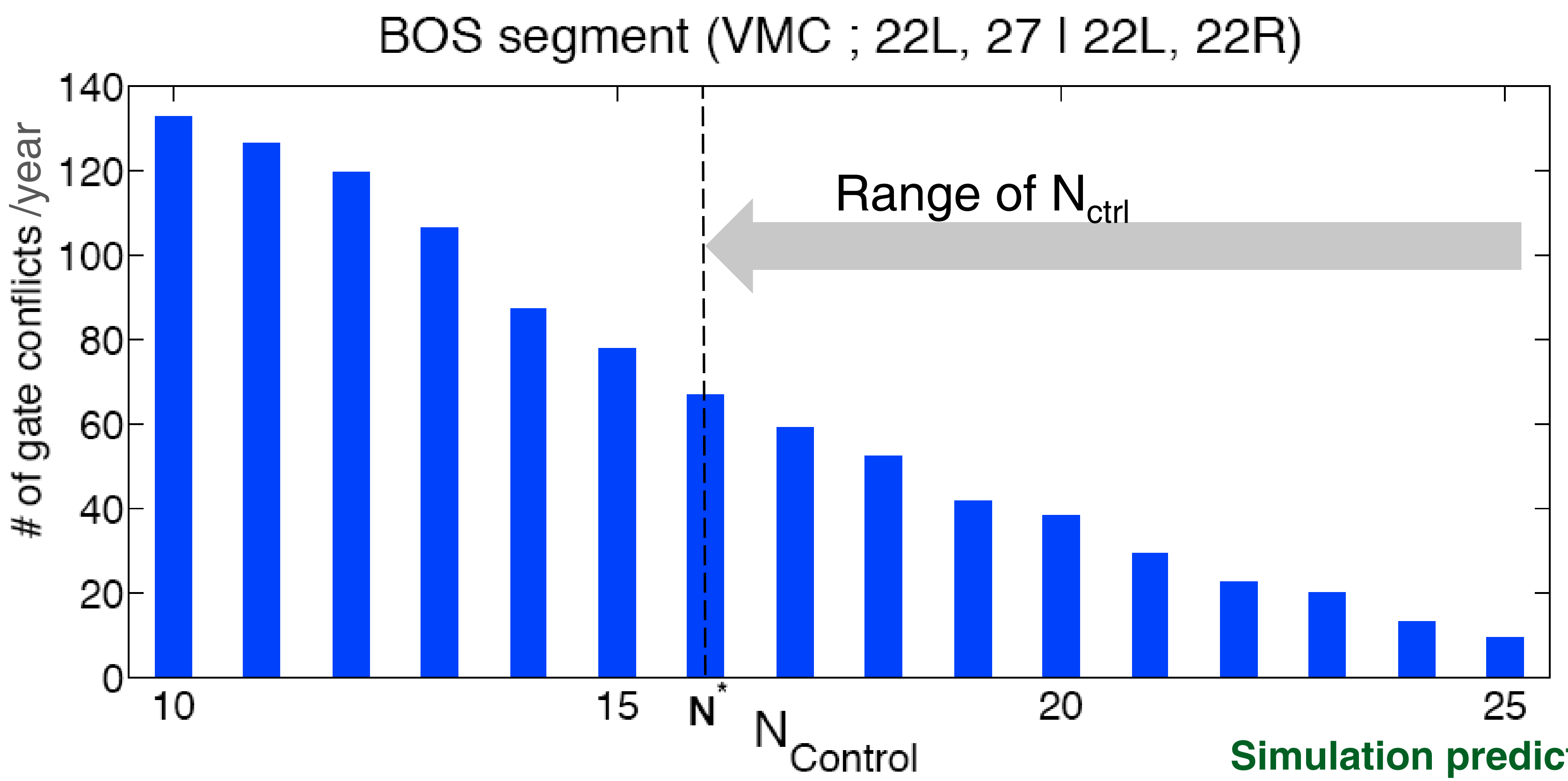
N_{ctrl}	10	15	16	17	18	19	20	21	22
Fuel burn (gallons)	206,954	65,557	52,927	43,575	34,949	27,780	21,899	17,150	13,164
HC (kg)	1,374	443	359	301	245	196	156	123	95
CO (kg)	14,416	4,663	3,786	3,142	2,540	2,027	1,618	1,270	981
NOx (kg)	2,615	830	670	551	441	351	276	216	166

Implementation challenges: Gate conflicts



Implementation challenges: Expected number of gate conflicts/year

- Gate conflict defined as event when an (arriving) aircraft is assigned the gate in which a departure is being held
- Number of gate conflicts increase as N_{ctrl} decreases



Simulation predictions

Implementation issues to be addressed

- Airport geometry, taxi procedures, dynamics must be understood
- Many issues need to be assessed with input from local stakeholders (tower, airport operator, carriers)
  - Controller procedures, “Call ready” protocols
  - Ramp management; Gate ownership, availability, scheduling
  - Sequence basis and fairness
  - Taxi time variability
  - Taxi paths, holding areas, penalty box locations
  - BTS on-time performance statistics
    - Modify policy to base statistics on “call ready to push”?
    - Gaming concerns
    - Increased predictability and decrease in long taxi delays: benefit with respect to Passenger Bill of Rights

Summary

- N-control is a conceptually simple strategy to limit the build up of surface queues
- Propose to demonstrate fuel burn and emissions reduction through N-control field test
  - Risk-mitigation strategy: Begin at high value of N_{ctrl} and decrease gradually
  - Potential fuel and emissions savings even at high N_{ctrl}
  - Gate conflicts and other operational issues will be carefully monitored
- Evaluation of operational and implementation issues
  - Need to be identified and addressed in cooperation with stakeholders