

MIT Lincoln Laboratory



Partnership for AiR Transportation  
Noise and Emissions Reduction

## Demonstration of Reduced Taxi Congestion at BOS through Airport Surface Movement Optimization Strategies

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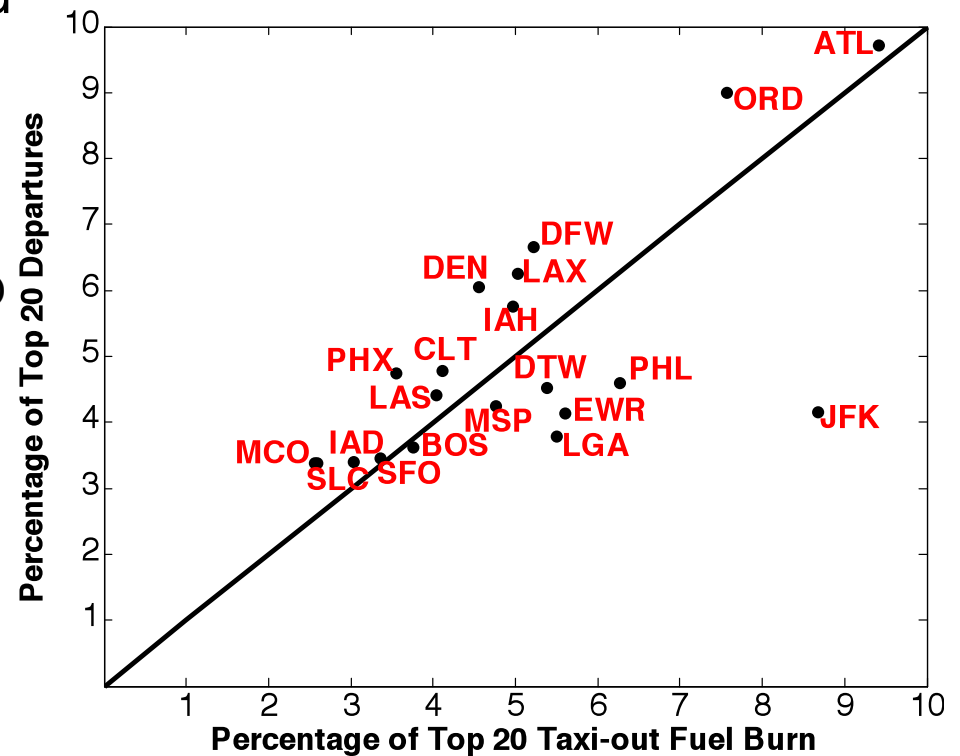
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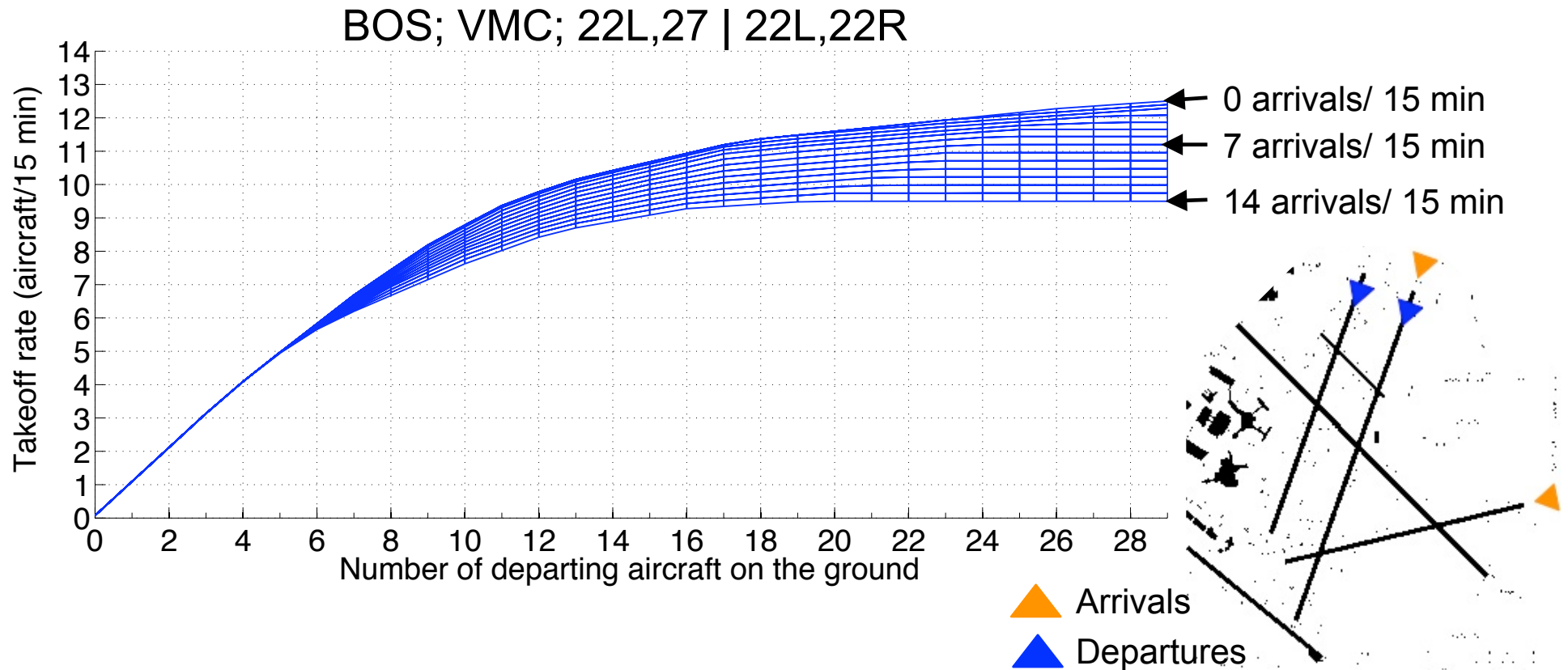


# Introduction

- Airport surface congestion leads to increased taxi times, fuel burn and emissions
  - Nationally (2007 ASPM)
    - 150 million minutes taxi-out, 63 million minutes taxi-in
    - 6 million tons CO<sub>2</sub>, 45,000 tons CO
    - 8,000 tons NO<sub>x</sub>
    - 4,000 tons hydrocarbons
  - BOS (2008 ASPM)
    - 3.2 million minutes taxi-out, 1.2 million mins taxi-in
    - 151,000 tons CO<sub>2</sub>, 1,100 tons CO
    - 201 tons NO<sub>x</sub>
    - 104 tons hydrocarbons



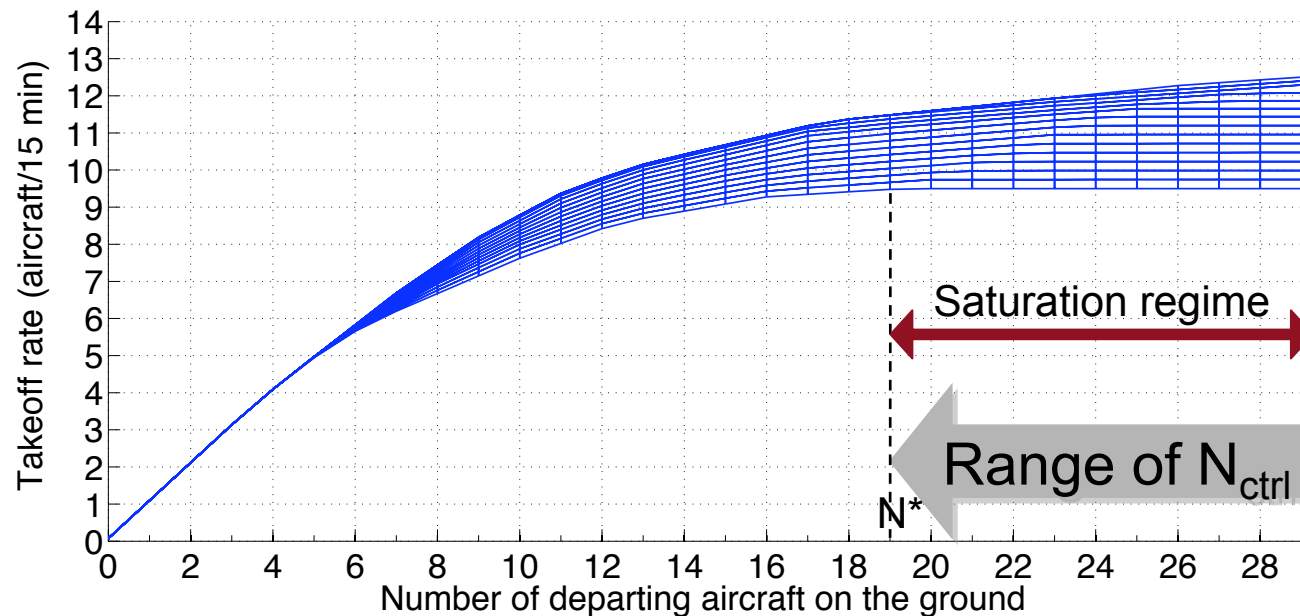
# Motivation for control strategy: Departure throughput saturation



- Curves can be defined for different configurations and IMC/VMC

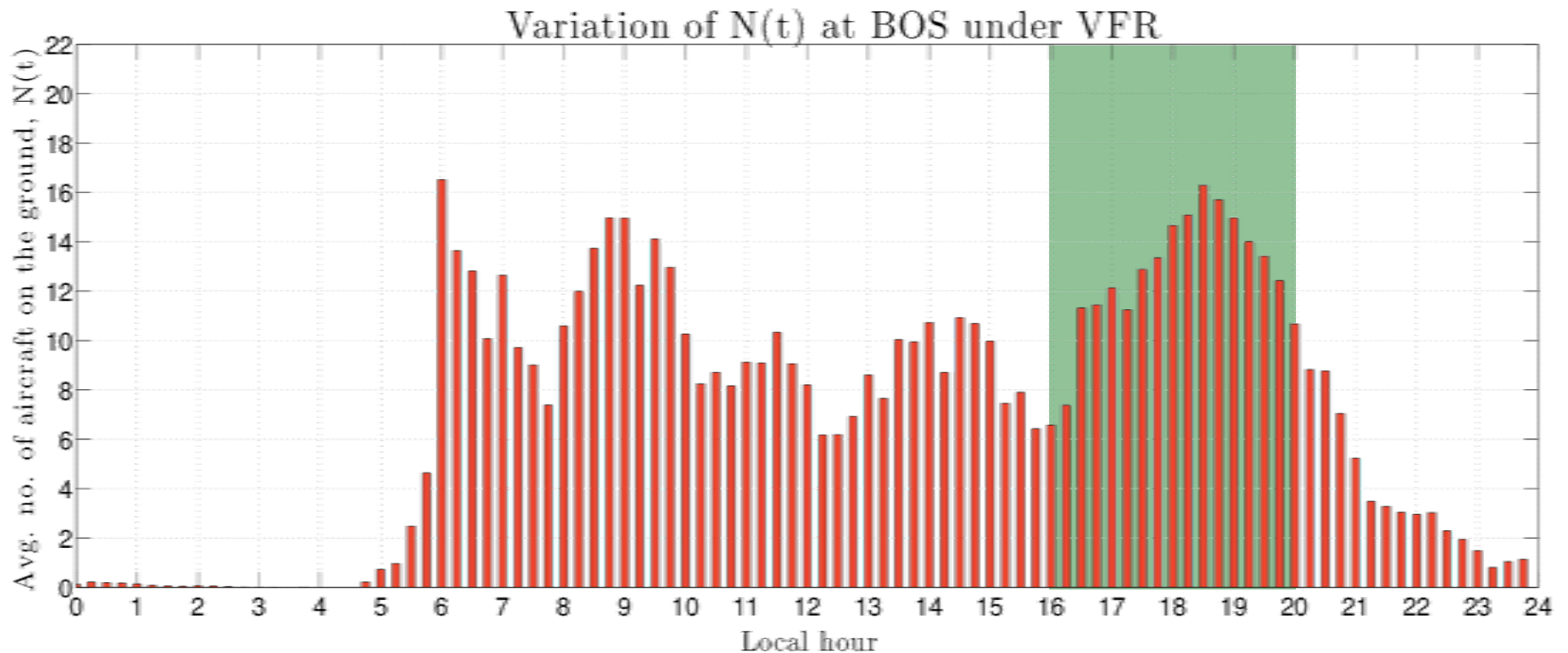
## Simple control strategy: “N-Control”

- Departure runway throughput “saturated” when number of aircraft pushed back (denoted  $N$ ) is greater than  $N^*$
- Try to keep  $N$  during congested periods close to some value ( $N_{ctrl}$ ), where  $N_{ctrl} > N^*$



# Demo of N-Control concept at Boston Logan airport

- 16 demo periods between Aug 23 and Sept 24
- Focus on 4PM-8PM departure push

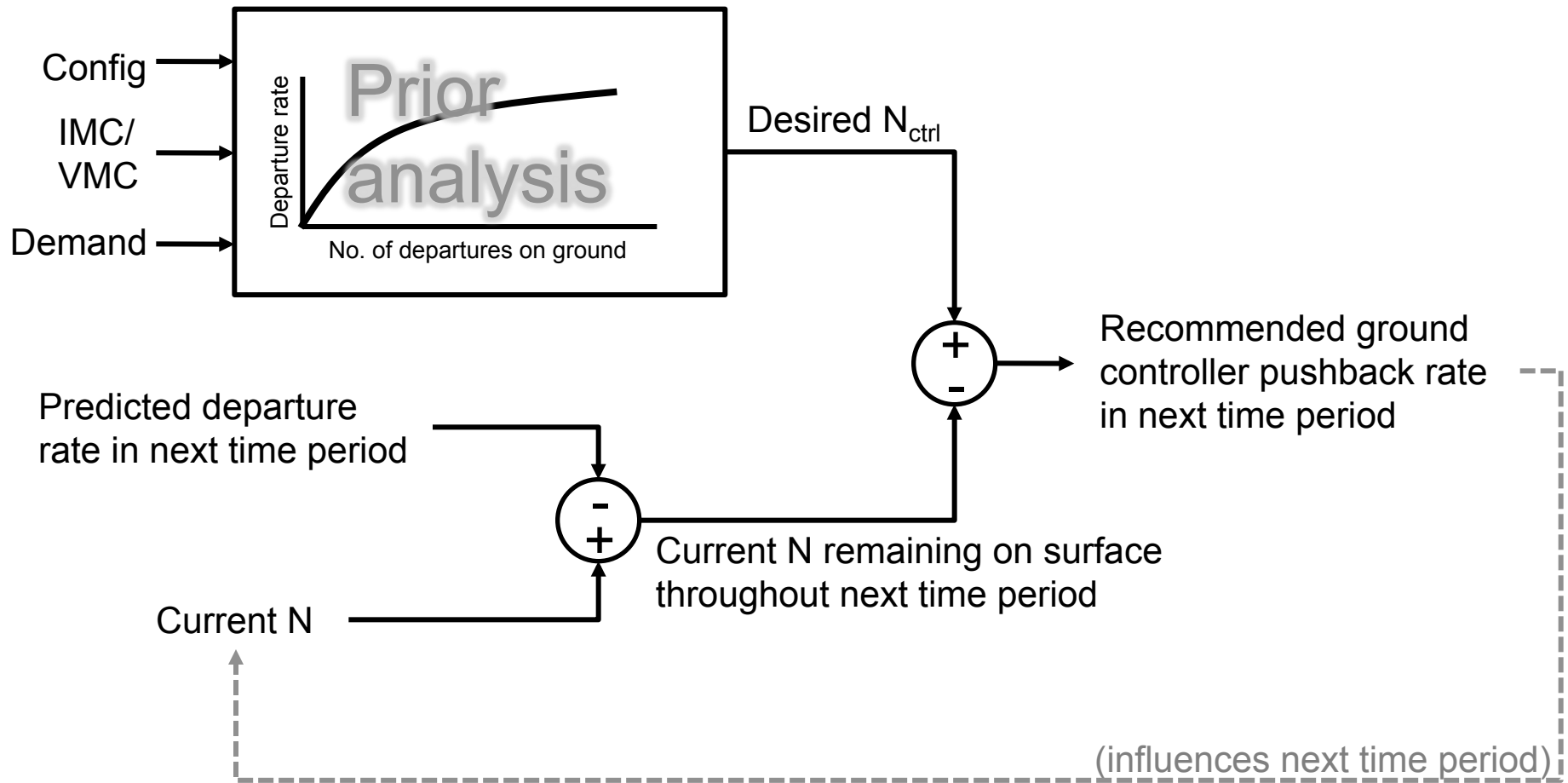


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## Objectives of demo

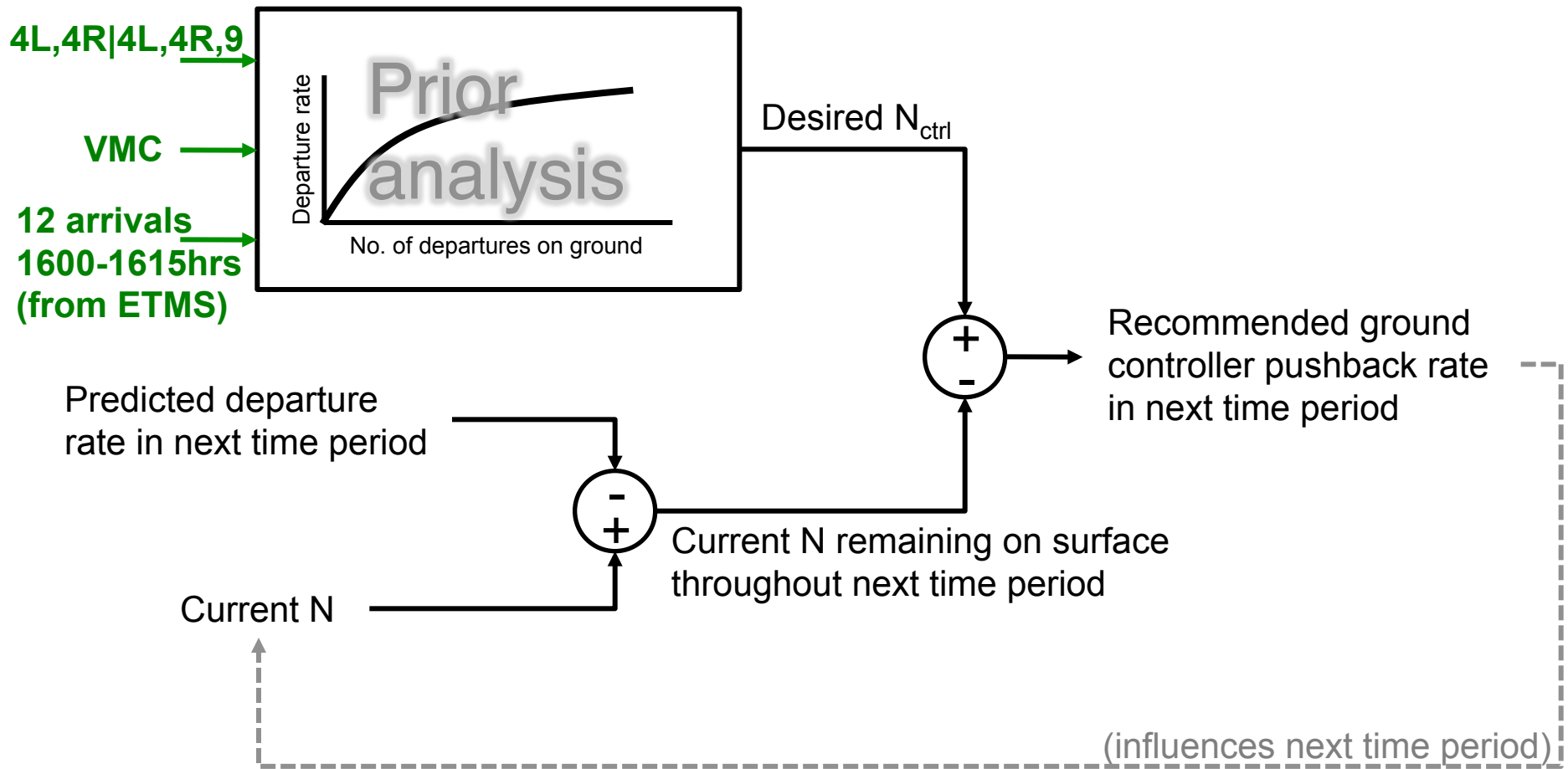
- Demonstrate potential benefits (in terms of taxi-out time and fuel consumption) of N-control concept
  - Incorporate simple N-Control concepts into current operational procedures with minimal controller workload and procedural modifications
    - Risk mitigation: begin with large values of  $N_{ctrl}$  and decrease gradually
    - Monitor carefully for off-nominal events, gate-use conflicts, traffic flow management restrictions, etc.
    - First-Come First-Served
    - **Rate-based control** (i.e., suggest *rate* of aircraft pushbacks)
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# Schematic of approach: *Suggested rate* determination



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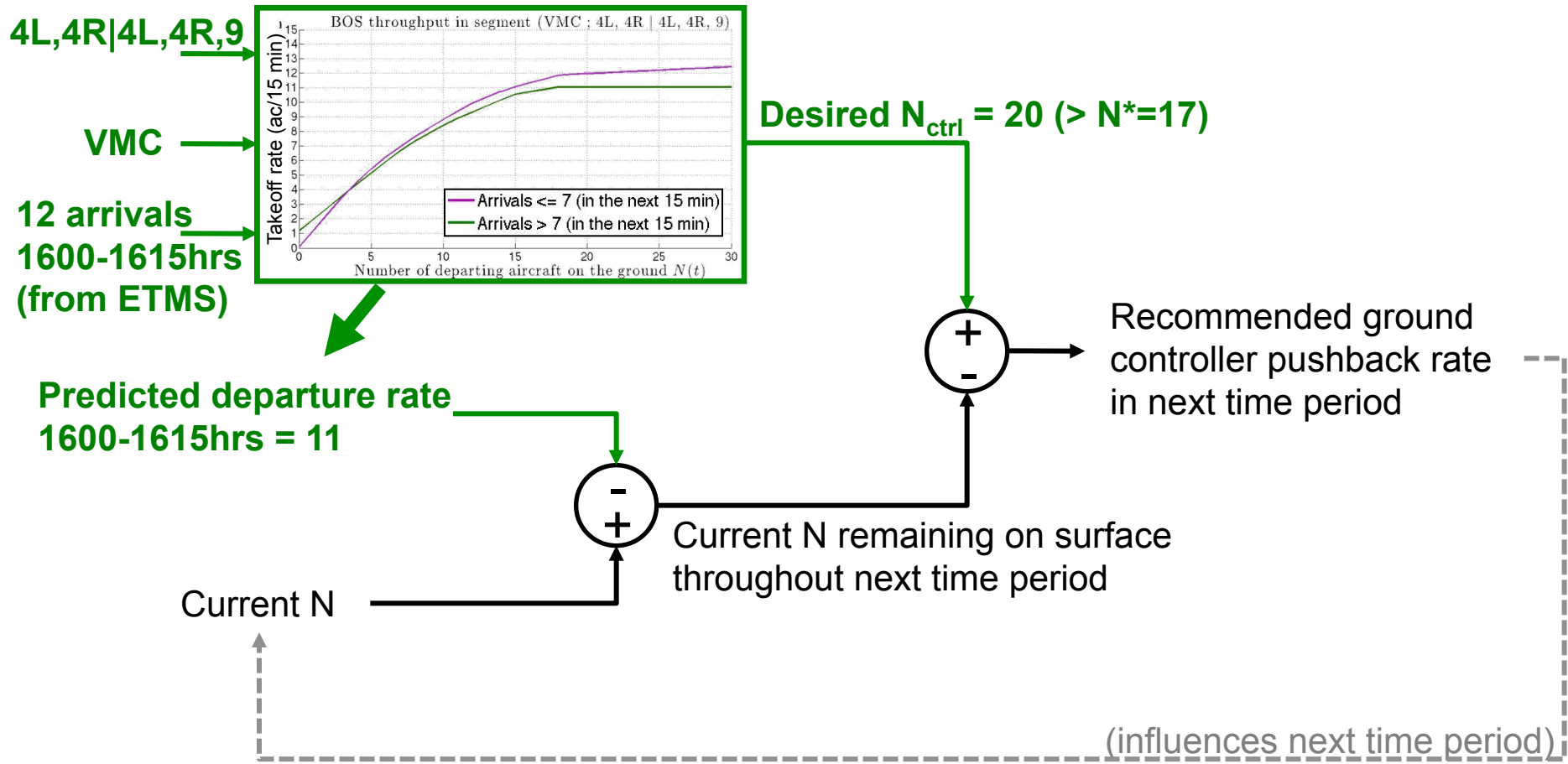
Current time 1558hrs





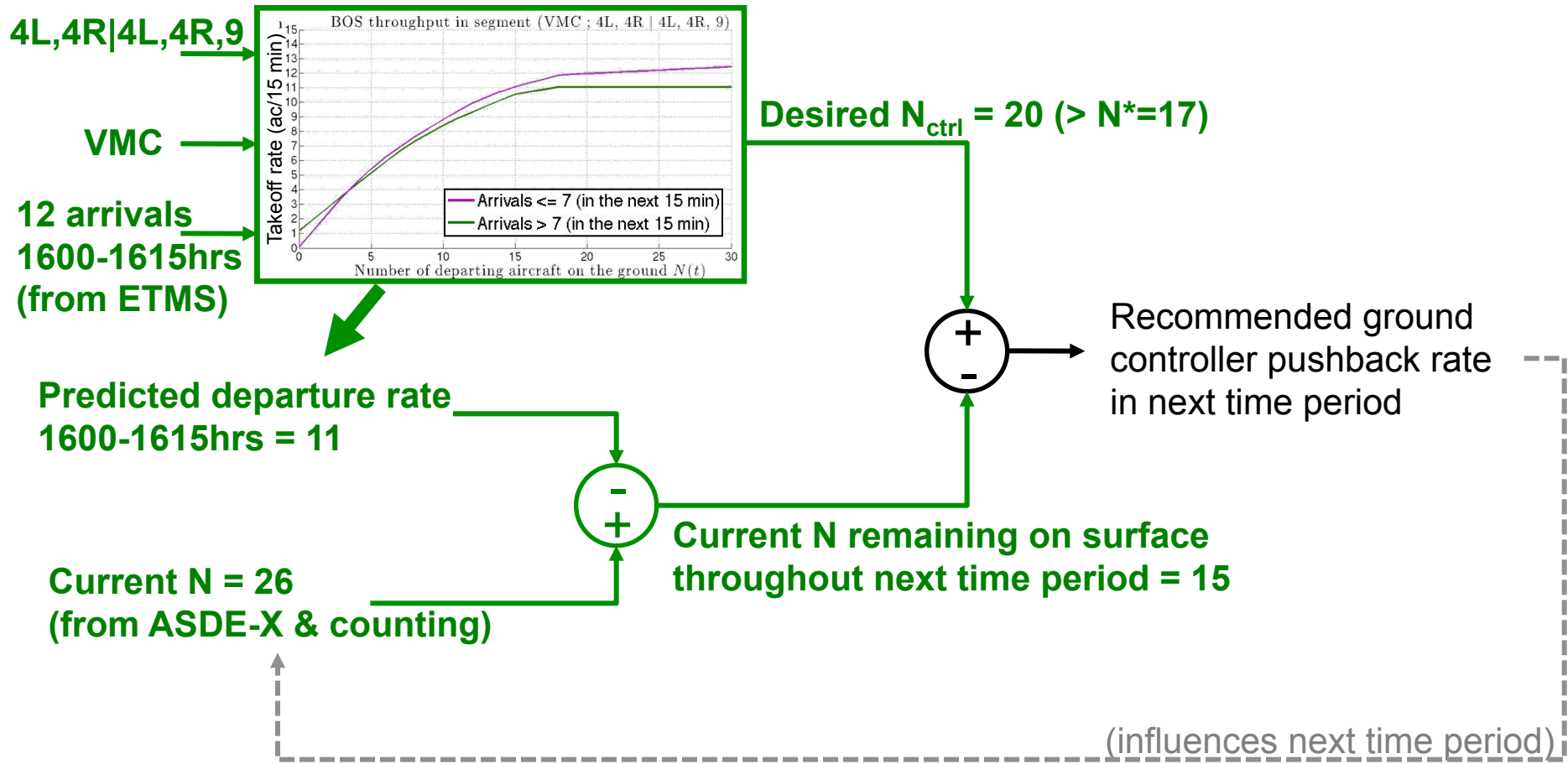
# Schematic of approach: *Suggested rate* determination

Current time 1558hrs



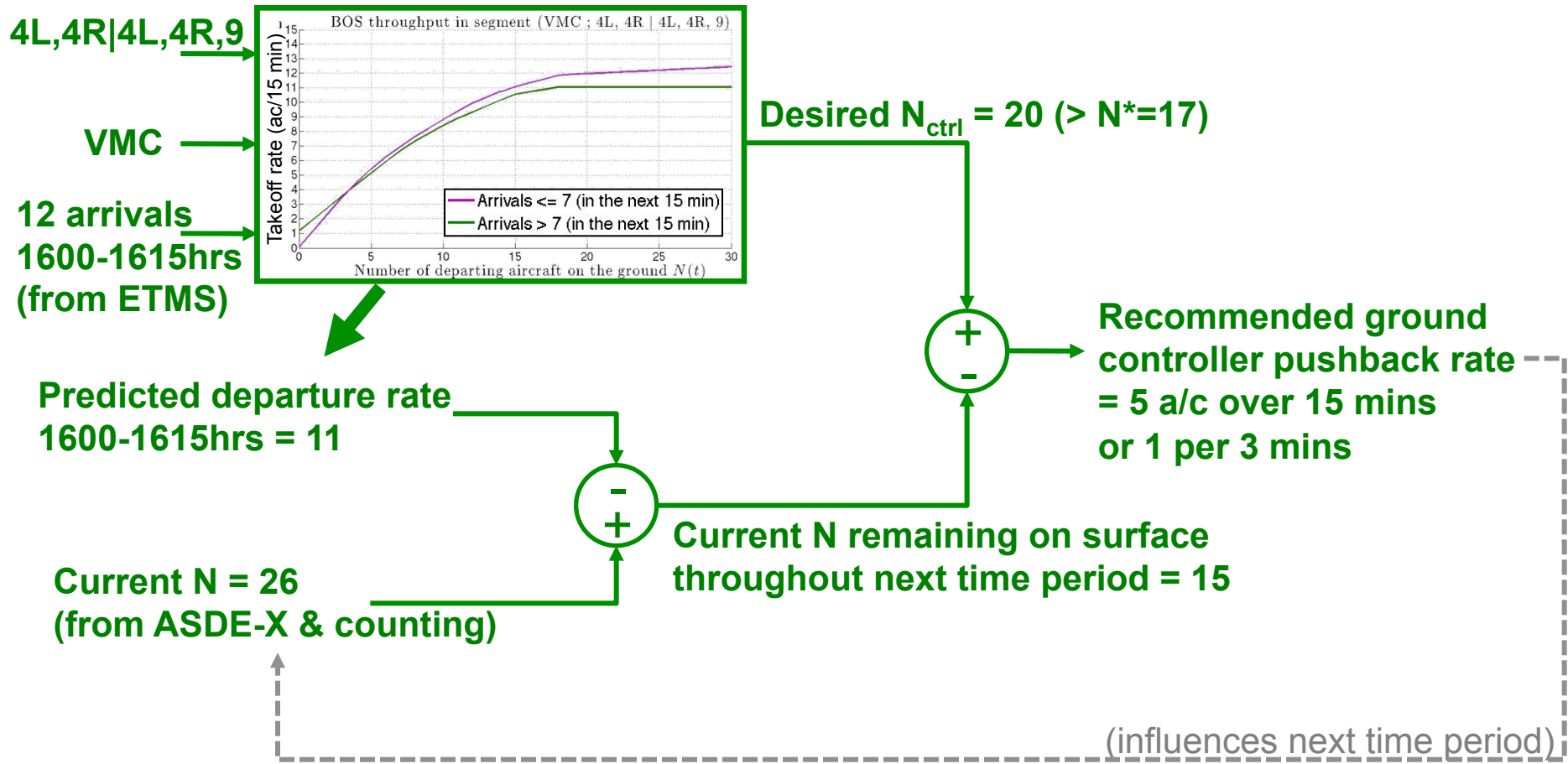
# Schematic of approach: *Suggested rate* determination

**Current time 1558hrs**



# Schematic of approach: *Suggested rate* determination

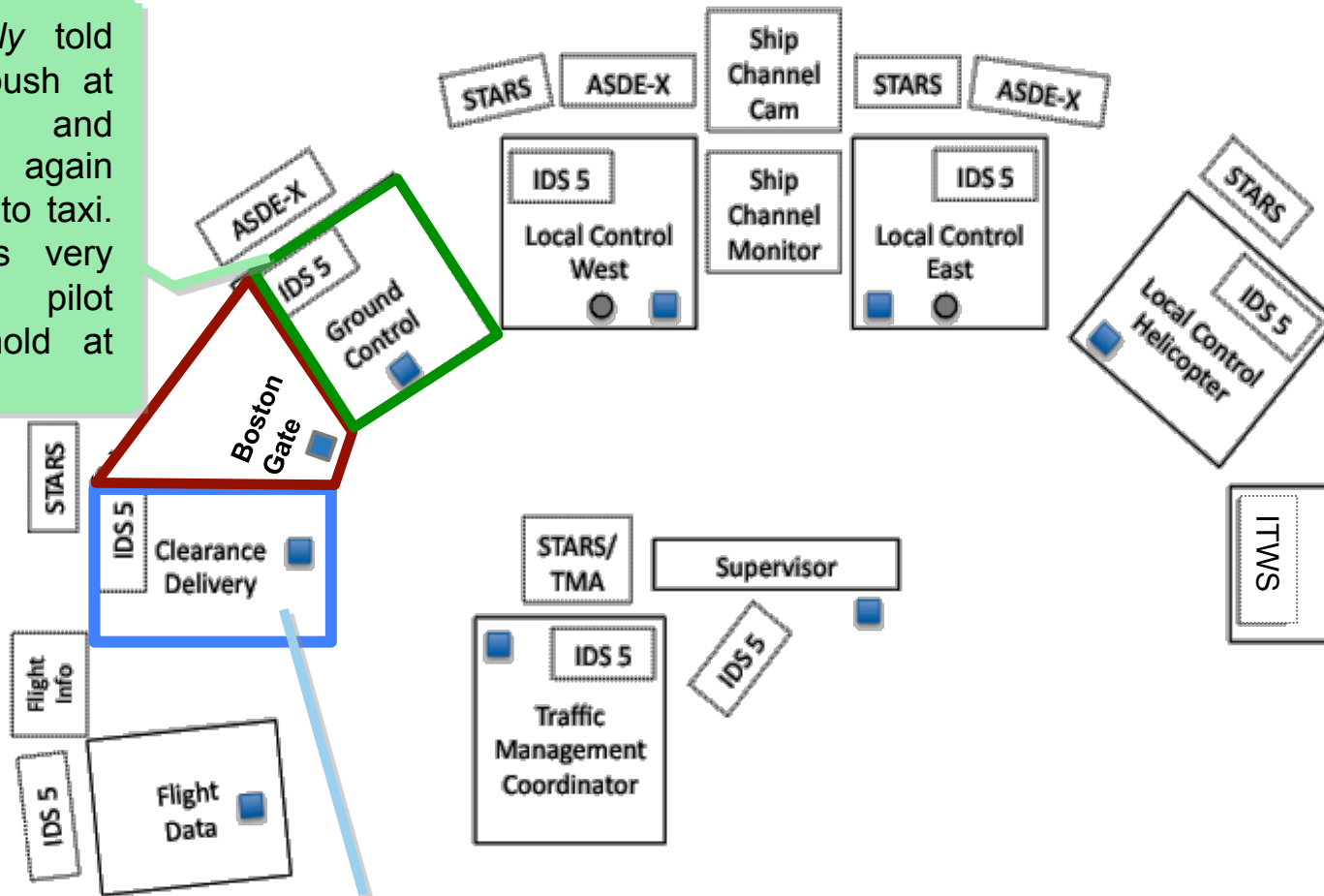
Current time 1558hrs



# Layout of BOS air traffic control tower

Pilot *typically* told by GC to push at discretion and contact GC again when ready to taxi. If airport is very congested, pilot asked to hold at gate.

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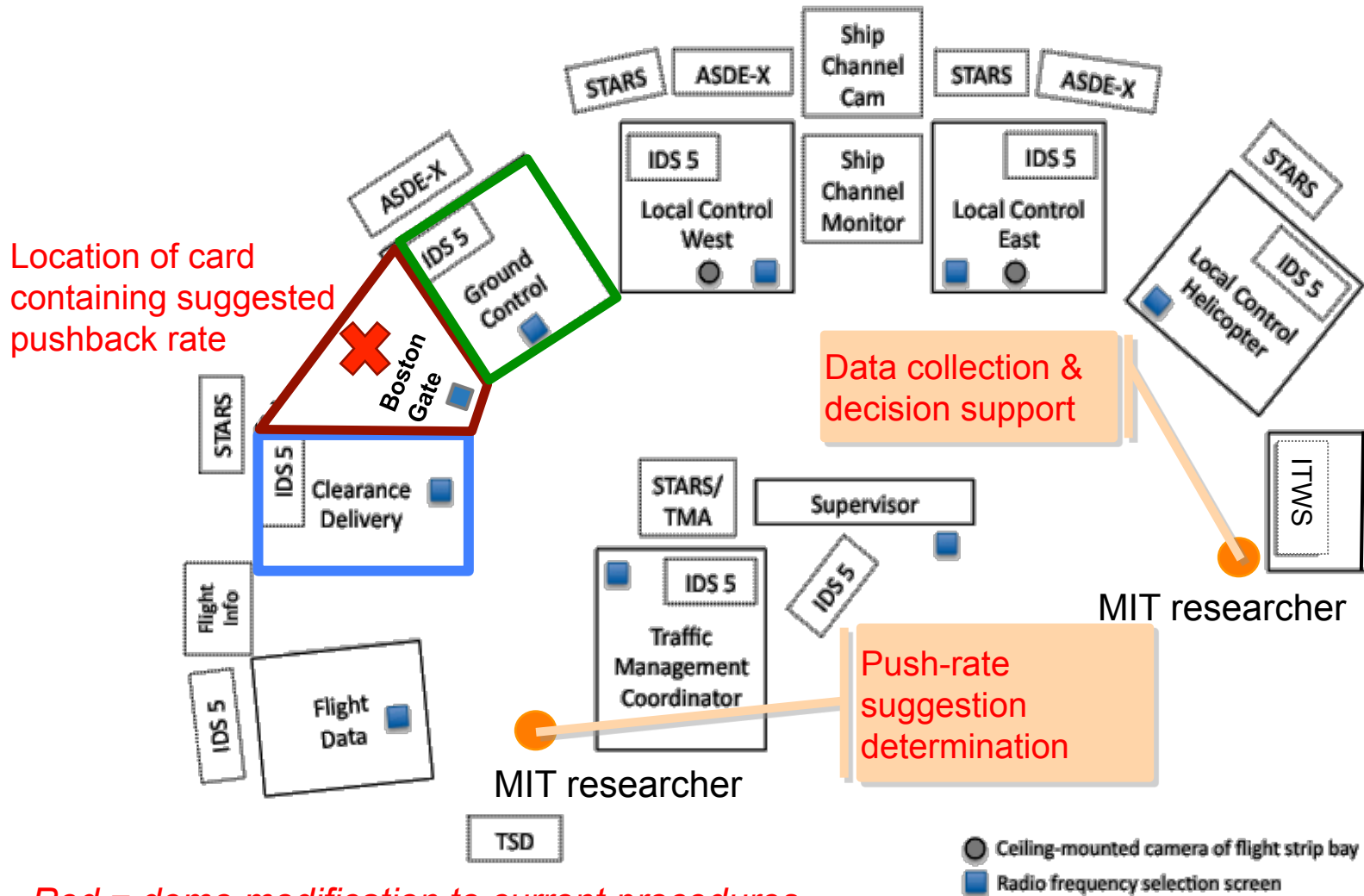


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Pilot contacts CD when ready to push.  
CD issues "route of flight" clearance and pilot told to monitor GC.  
CD passes flight strip and control to GC.

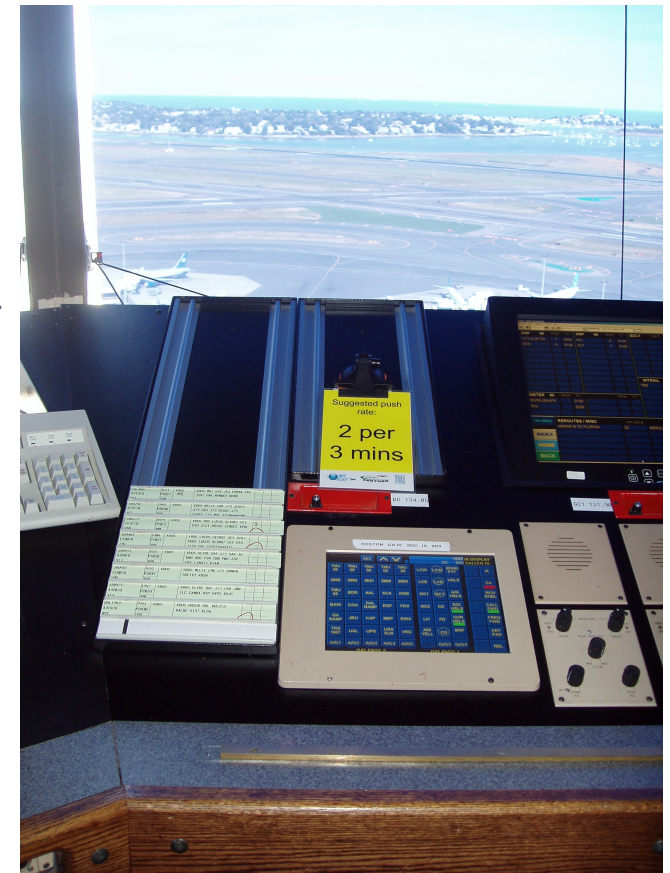
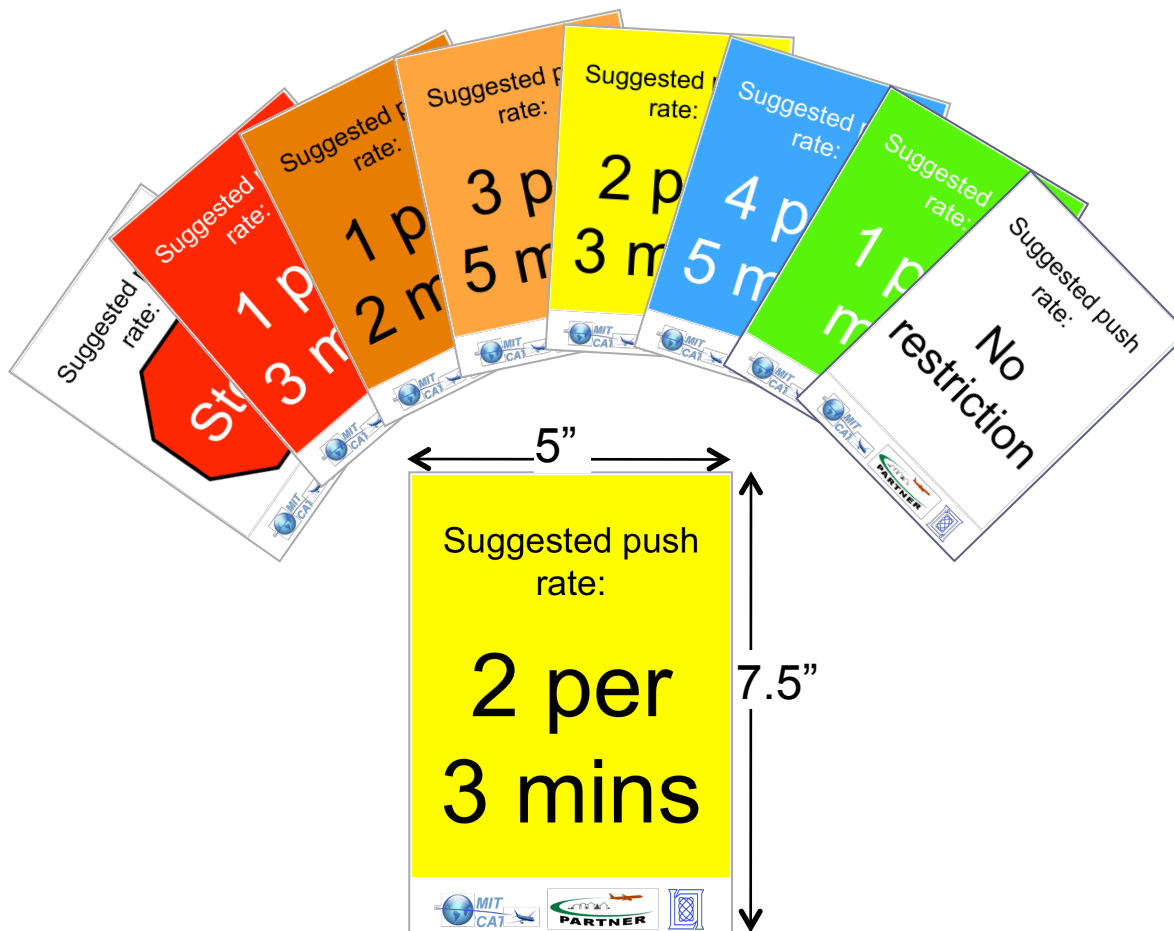
● Ceiling-mounted camera of flight strip bay  
■ Radio frequency selection screen

# Demo setup

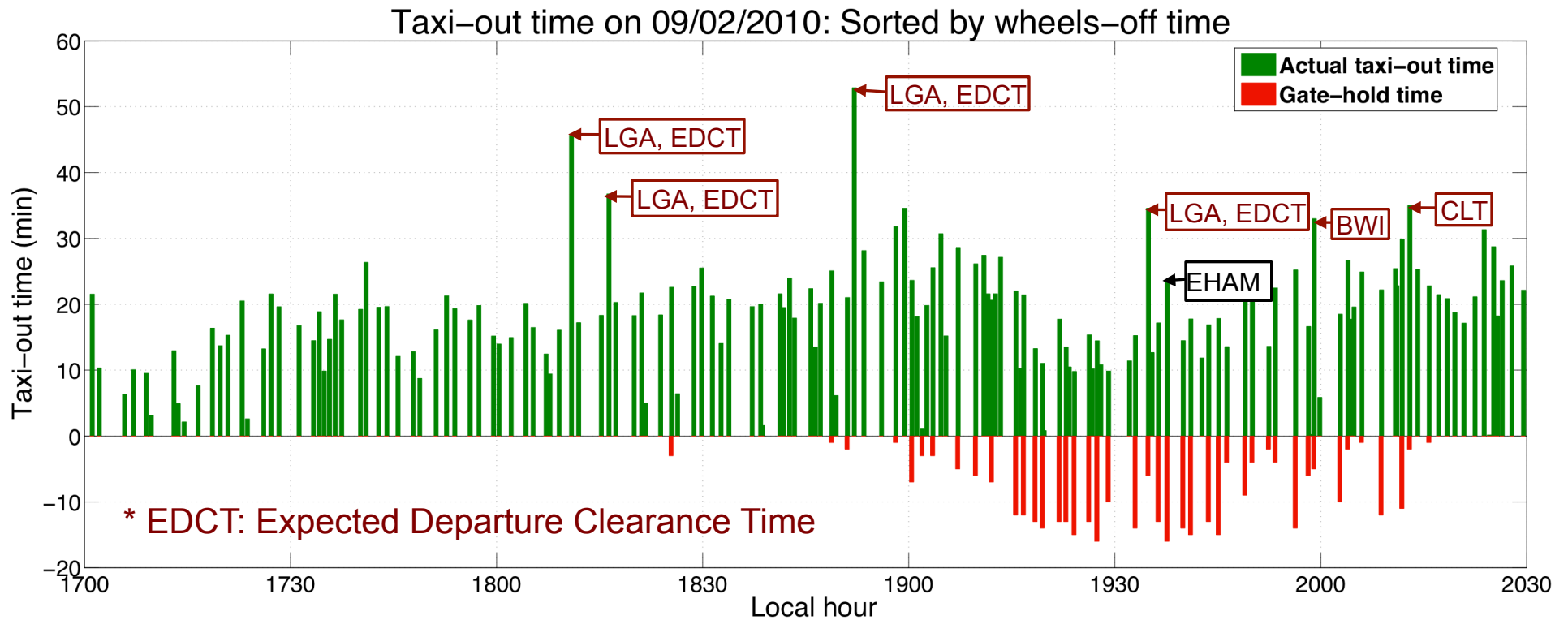


# Communicating suggested push rate

- Suggest pushback rates using color-coded cards
- No verbal communications with tactical air traffic controllers



# Gate-holds from a sample demo period



- Maintained runway utilization during metering: 3 min of “dry runway” in > 35 hours of active rate control of pushbacks

# Playback of surface surveillance data





# Visualization of ASDE-X data

Before

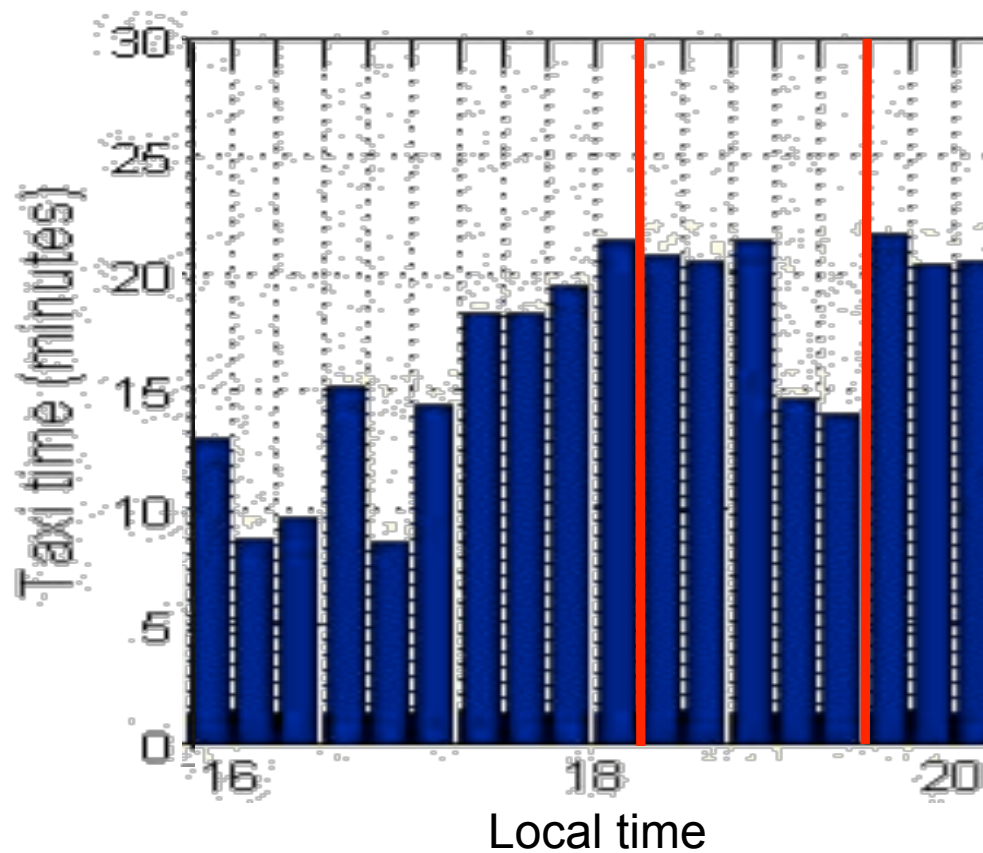


During metering



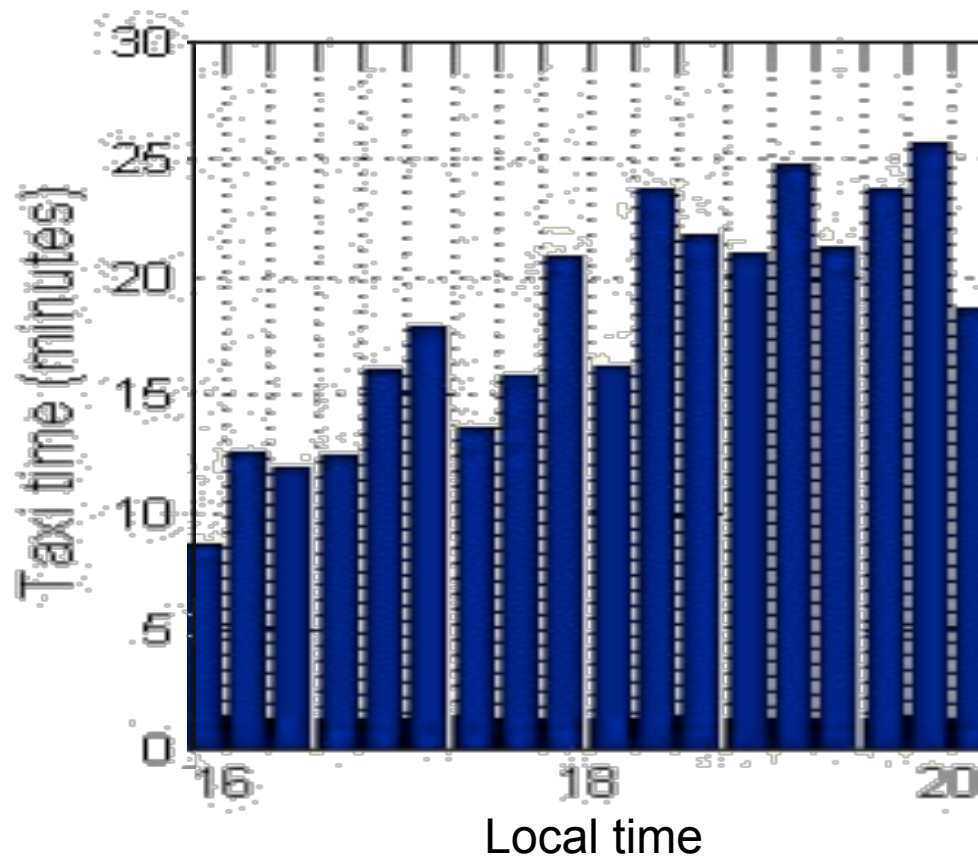
## Average taxi-out times with metering

- Average taxi-out times on the evening of Sept 2, 2010
- Gate-holds in effect between 1815 and 1930



## Average taxi-out times without metering

- Average taxi-out times on the evening of August 17, 2010
- Evening with similar demand as Sept 2, but no metering



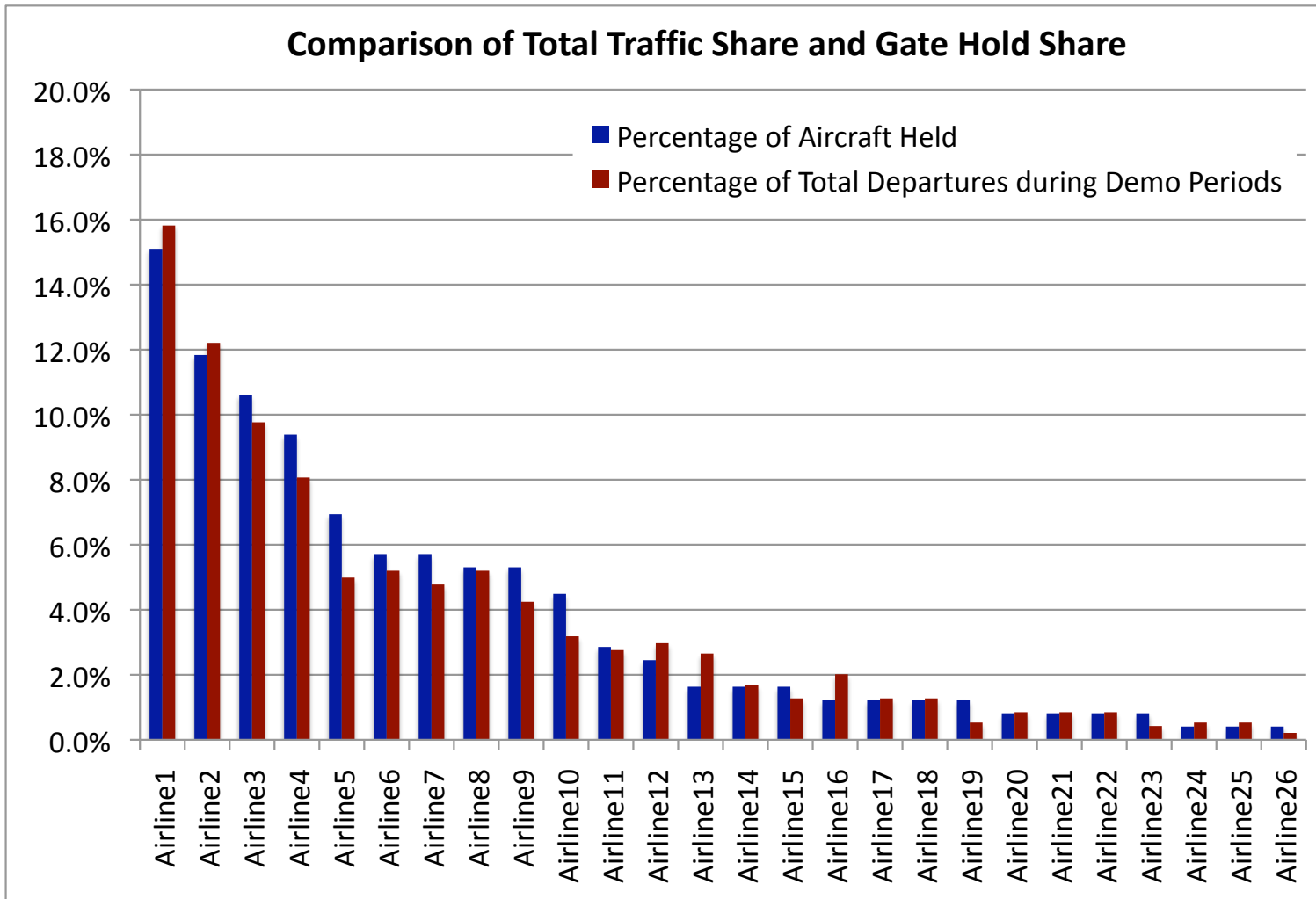
## Preliminary results of BOS field tests

	Date	Time Period	Configuration	Number of Gate-holds	Avg. gate-hold (min)	Total gate-hold (taxi time savings, min)
1.	8/26	4.45-8PM	27, 22L   22R	62	4.06	268
2.	8/29	4.45-8PM	27, 32   33L	35	3.24	110
3.	8/30	5-8PM	27, 32   33L	8	4.75	38
4.	9/2	4.45-8PM	27, 22L   22R	45	8.33	375
5.	9/3	4-7.45PM	4R   9	0	0	0
6.	9/6	5-8PM	27, 22L   22R	18	2.21	42
7.	9/7	5-7.45PM	27, 22L   22R	11	2.09	23
8.	9/9	5-8PM	27, 32   33L	11	2.18	24
9.	9/10	5-8PM	27, 32   33L	56	3.70	207
10.	9/12	4.45-7.30PM	4L, 4R   9	0	0	0
11.	9/17	4.45-7.30PM	4L, 4R   9	1	2	2
<b>Total</b>		<b>37 hrs</b>		<b>247</b>	<b>4.3 min</b>	<b>1063 min = 17.7 hours</b>

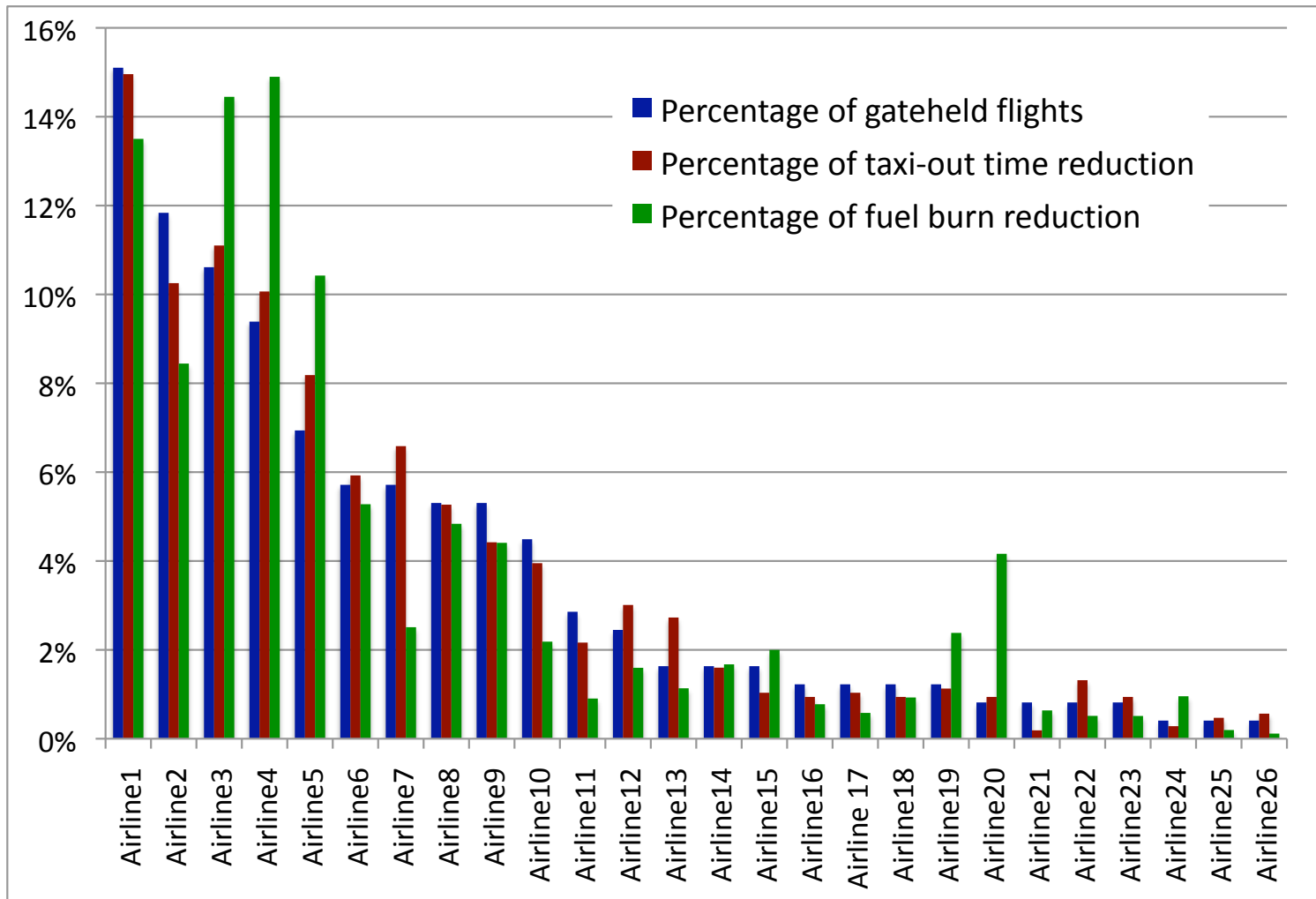
No metering during test periods on  
8/23, 9/16, 9/19, 9/24

≈ 12,000-5,000 kg of fuel saved  
(holds with engines off; APU on or off)

# Number of gateholds commensurate with traffic



# Fuel burn reduction depends on aircraft fleet mix



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## Some early observations

- N-Control requires congestion to work (as expected)
    - Very little metering in most efficient configuration (4L,4R |9)
  - Can handle target departure times (e.g., EDCTs)
    - Preferable to get EDCTs while still at gate
  - Many factors drive throughput, but approach can adapt to variability
    - Heavy landings on departure runway, arrivals, controller crossing strategies, birds on runway,...
  - Controllers have different strategies to implement suggested rate
  - Need to consider ground crew constraints, gate-use conflicts, different taxi procedures for international flights, etc.
  - Significant benefits seen even from preliminary analysis
    - 4.3 min decrease in taxi-out times
    - 50-60 kg decrease in fuel burn per gate-held flight
    - In the most congested periods, up to 44% of flights experienced gate-holds
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## Summary

- Demo of incorporating N-Control techniques into current operational procedures with minimal controller/pilot workload and procedural modifications
    - Use of rate cards for conveying pushback rates to controllers
    - Risk-mitigation:
      - Conservative values of  $N_{ctrl}$
      - Carefully identify, monitor and address off-nominal events/other issues
    - Intensive demo of concept over 16 periods of 3-4 hours each
    - Targeted 4PM-8PM time frame (Aug 23–Sept 23, 2010)
  - Identified and monitored implementation issues
    - Daily debrief telecon with airline reps, BOS tower, FAA, Massport
    - Approaches to accommodate EDCTs, gate-use conflicts, track gate-holds, etc.
  - Next steps:
    - Evaluate general applicability of N-Control concept
    - Detailed evaluation of benefits (in terms of taxi-out time, fuel burn and emissions reduction) of N-control concept
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