



ACS-Lite FHWA adaptive control for closed-loop systems

Raj S. Ghaman, PE
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U.S. Department of Transportation
Federal Highway Administration

Outline

- Goals
- System architecture
- Adaptive approach
 - Cyclic performance measures
- Field trials



Adaptive in the U.S. (FHWA)

- **1970s-1980s: UTCS**
 - Second by second central
- **1990s: Predictive control (ACS)**
 - FHWA ACS: RHODES, OPAC
 - Second by second distributed
- **2002: Controller-based Adaptive**
 - FHWA ACS “Lite”: Siemens ITS
 - Leverage existing hardware
 - Update controller parameters every five minutes



FHWA Goals for ACS-Lite

- Low cost design
- Leverage existing infrastructure
 - Standard US-style actuated controllers (rings, phases, splits, barriers)
 - Standard fully-actuated detector layouts
 - Standard NTCIP Communications
- “Retro-fit” with major US signal system vendors



Project Team



U.S. Department of Transportation
Federal Highway Administration

SIEMENS



EAGLE Traffic Control Systems

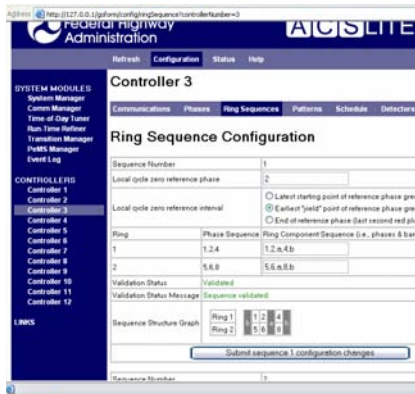


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System Architecture

9600bps, up to 12 controllers

ACS-Lite



Field Processor

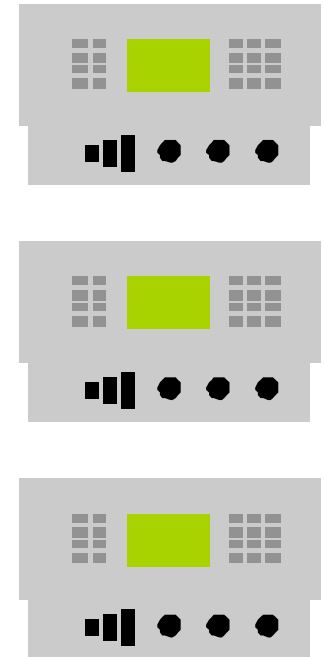
Optional
Protocol
Translation

NTCIP

Vendor Specific
or NTCIP

Vendor
Field Master

Optional

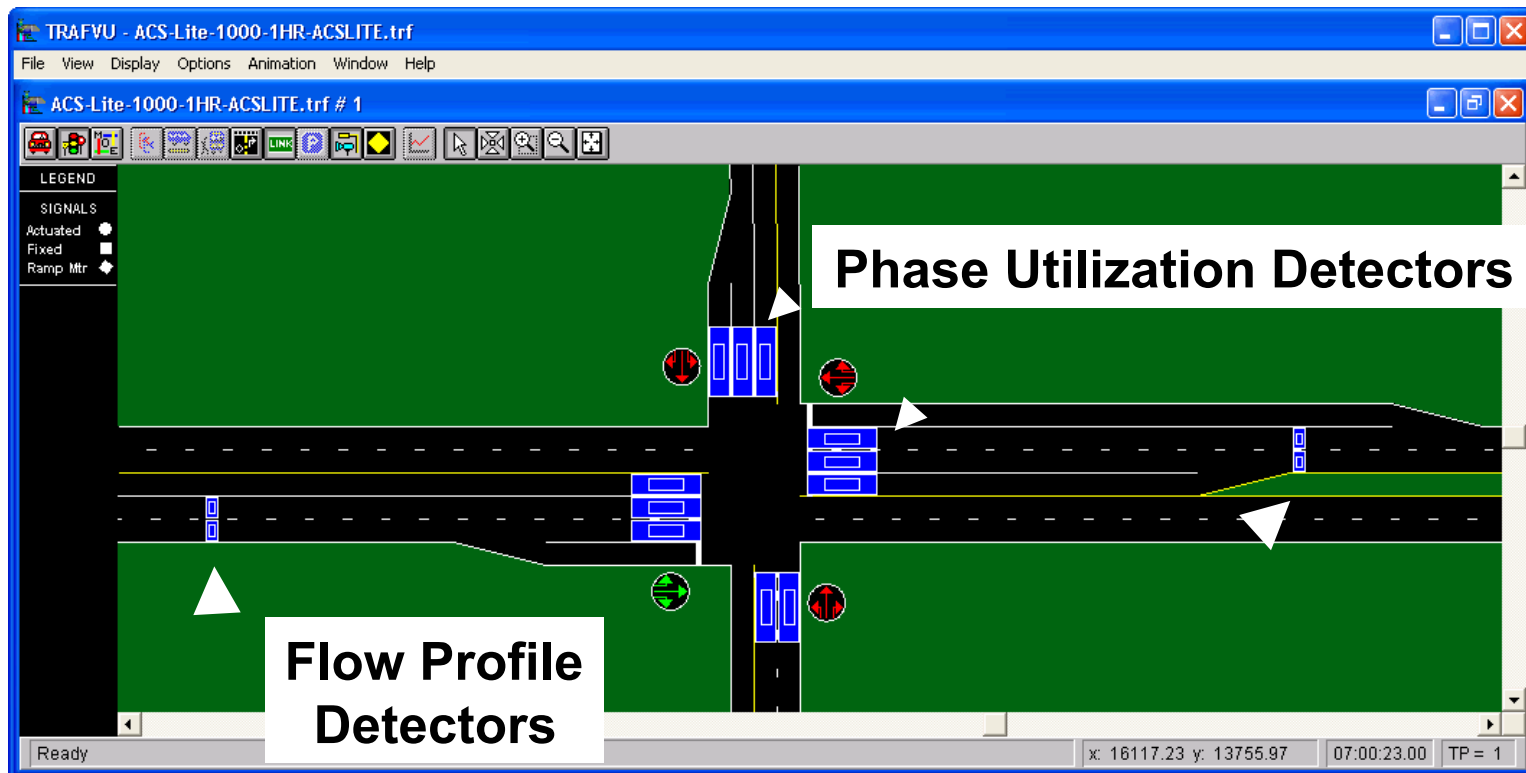


NTCIP + ACS-Lite
firmware upgrade



ACS-Lite Detection Layout

Need detectors at stop-bar of coordinated phases



ACS-Lite adaptive control philosophy

- Data-driven parameter tuning
- Limited/no traffic modeling
- Recent past predicts the near future

1

- Splits
 - Phase Utilization

2

- Offsets
 - Statistical Flow Profiles



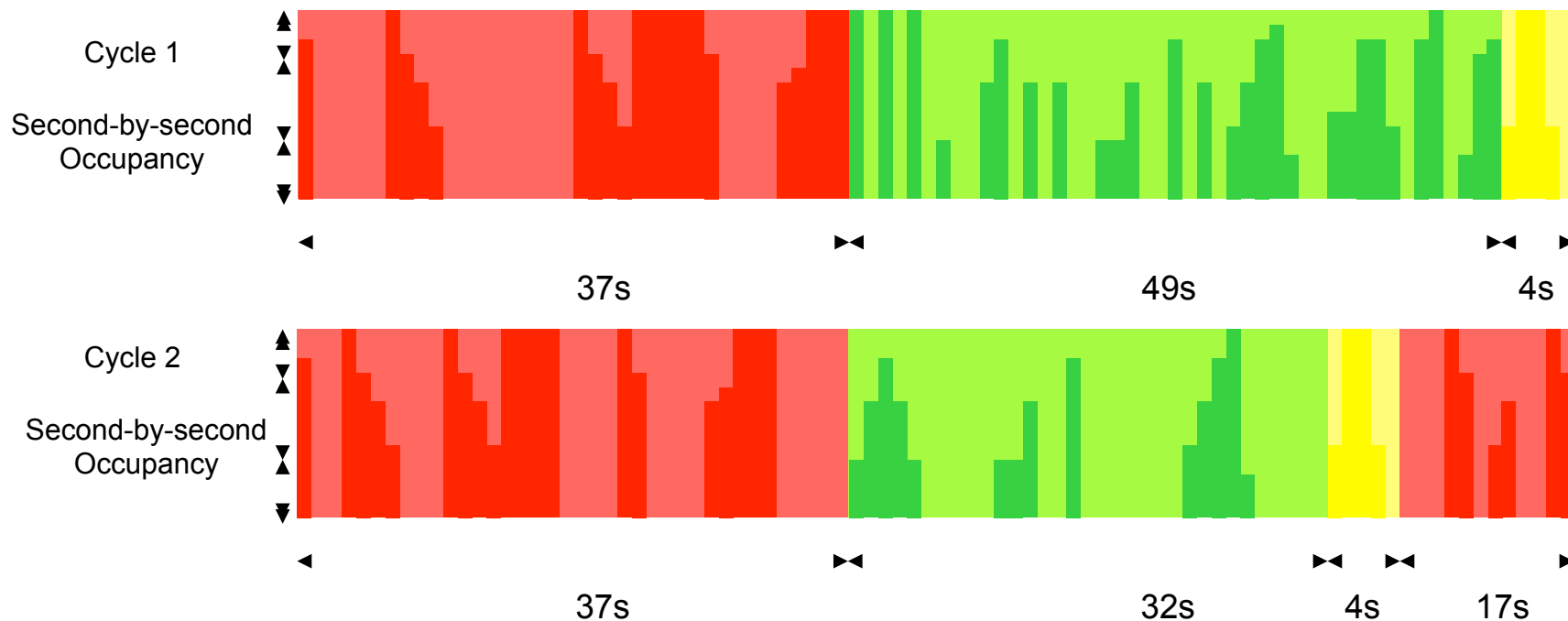
ACS-Lite NTCIP firmware upgrade

- 1 • Phase Timing Status Object
- 2 • Detector Status Object
- 3 • Configuration Objects
 - Polled once per minute
 - Second-by-second accuracy
 - Bandwidth efficient
 - Minute-by-minute polls are “stitched” together for cycle-by-cycle performance assessment



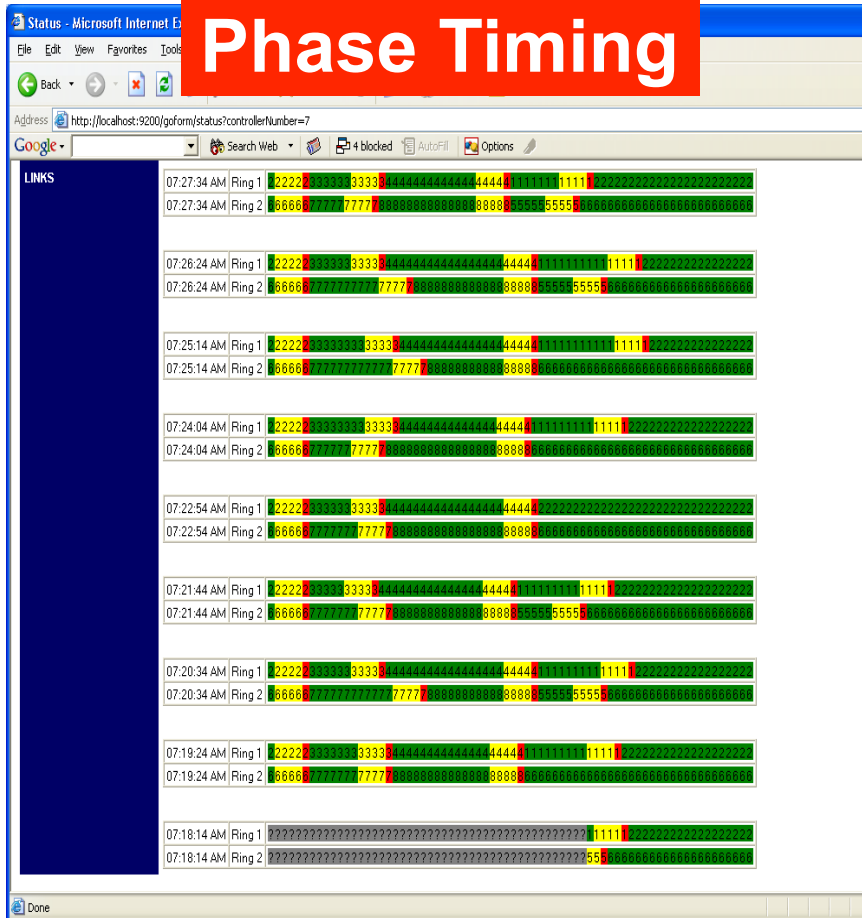
Occupancy per phase interval

- Occupancy values per second
- Correlated to Red/Green/Yellow

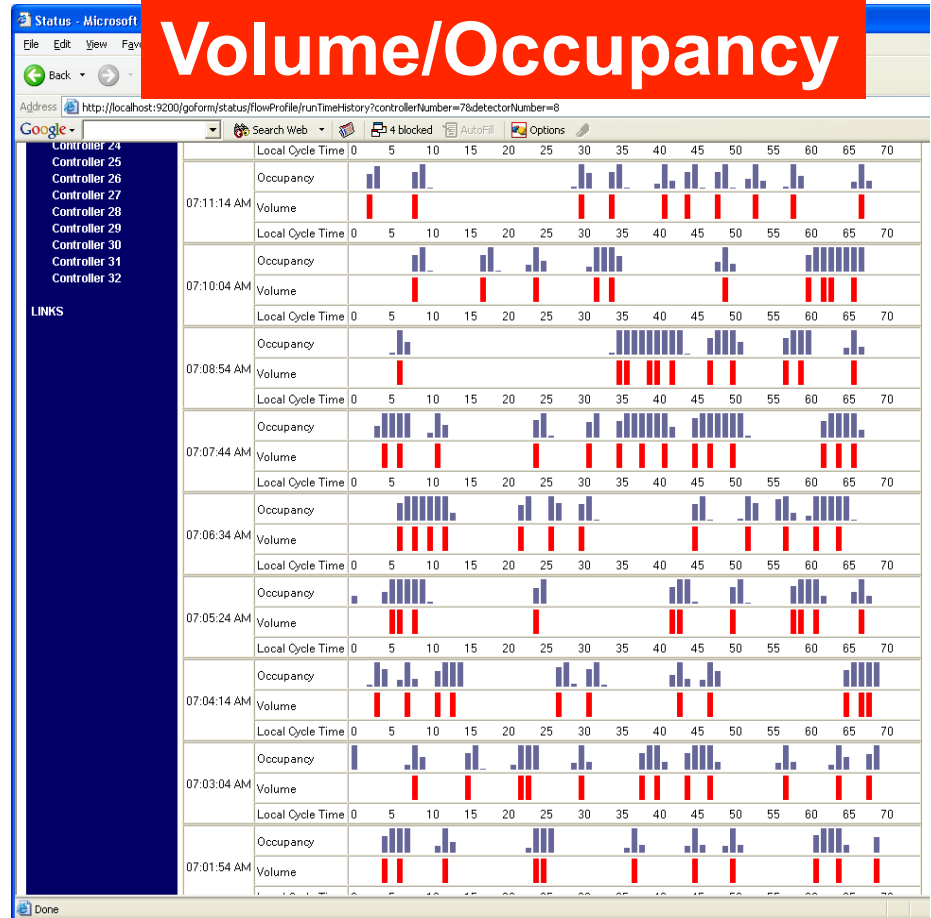


Cycle-by-cycle Data

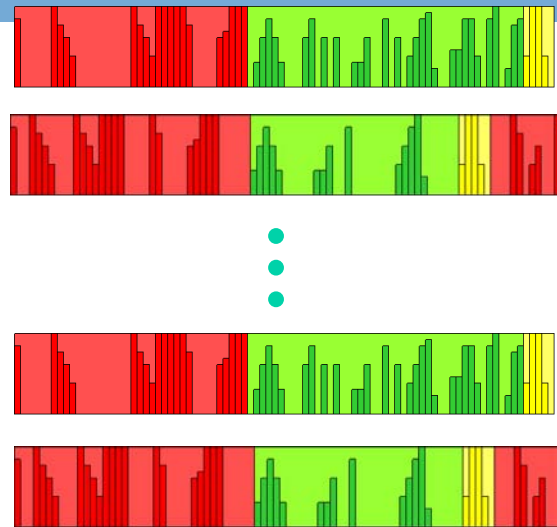
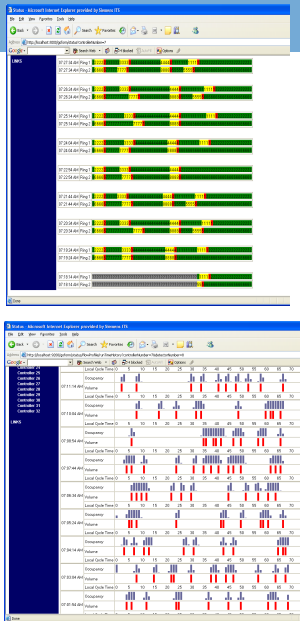
Phase Timing



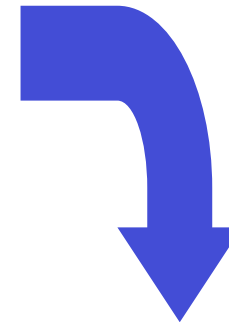
Volume/Occupancy



Occupancy per interval → split tuning



Averaging



Green occupancy → Phase Utilization

ACS LITE SIEMENS

Controller 7

Phase Timing Phase Utilization Flow Profile Pattern History Detectors Upload Files

Controller clock: 09:21:46 AM

Phase Number	Number of Observations	Gap-outs	Max-outs	Force-offs	Omits/Skips	Termination Timeline	Average Green Time (sec)	Average Green Occupancy (%)	Average Used Green (sec)	Average Available Green (sec)	Average Phase Utilization (%)	Degree of Saturation	Average Phase Demand (% time)	Minimum Split	Current Split	Maximum Split
1	12 (100%)	10 (83%)	0 (0%)	0 (0%)	2 (16%)	G.O.G.G.G.G.G.O.G.G.G.G.	7.5	64%	6.30	14.5	43.0%	<div style="width: 43%;"></div>	9.0%	10	16	45
2	12 (100%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)	FFFFFFFFFFFF	23.7	67%	15.20	23.7	67.0%	<div style="width: 67%;"></div>	21.7%	20	21	85
3	12 (100%)	2 (16%)	0 (0%)	10 (83%)	0 (0%)	FF.F.F.F.F.F.F.F.F.F.F.	9.0	87%	7.48	9.3	85.3%	<div style="width: 85%;"></div>	10.6%	10	13	30
4	11 (100%)	8 (72%)	0 (0%)	2 (18%)	1 (9%)	G.G.O.O.F.F.F.F.F.F.F.F.	10.5	42%	4.81	19.2	31.6%	<div style="width: 31%;"></div>	6.8%	15		
5	12 (100%)	4 (33%)	0 (0%)	2 (16%)	6 (50%)	O.G.O.O.F.F.F.F.F.F.F.F.	2.6	37%	1.99	8.5	28.2%	<div style="width: 28%;"></div>	2.8%	10		
6	12 (100%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)	FFFFFFFFFFFF	30.3	59%	17.15	30.3	59.2%	<div style="width: 59%;"></div>	24.5%	20		
7	12 (100%)	5 (41%)	0 (0%)	1 (8%)	6 (50%)	O.G.O.O.F.F.F.F.F.F.F.F.	3.3	35%	2.56	12.0	21.3%	<div style="width: 21%;"></div>	3.6%	10		
8	12 (100%)	10 (83%)	0 (0%)	2 (16%)	0 (0%)	G.G.O.O.F.F.F.F.F.F.F.F.	18.3	78%	13.71	22.1	66.3%	<div style="width: 66%;"></div>	19.5%	15		

Ring 1 (1) 101625 (2) 2012135 (3) 101325 (4) 152030
(+) -809 (+) -1014 (+) -3012 (+) -5010

Ring 2 (5) 101025 (6) 202735 (7) 101725 (8) 151630
(+) 0015 (+) -708 (+) -708 (+) -1014

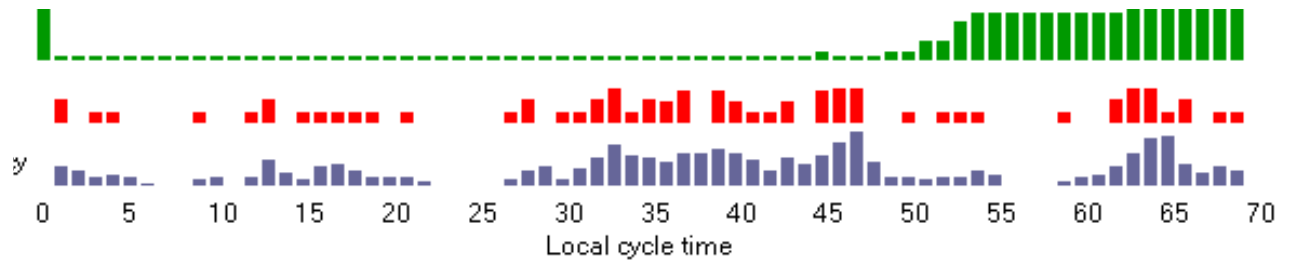
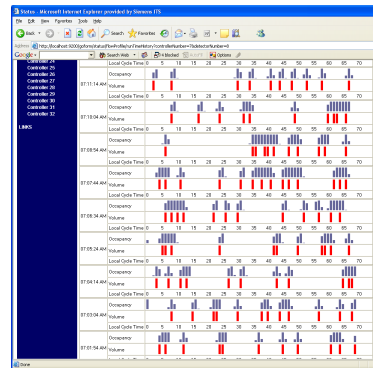
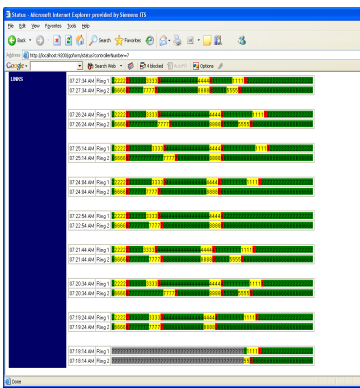
Barrier Groups (min/max) 3033745 (min/max) 253340
(min/max) 3033745 (min/max) 253340

Phase	Color	911	94%	100	016	0%	0	916	93%	100	519	35%	100	1517	91%	100	511	35%	100	1316	90%	100	011	0%	0	913	86%	100	713	82%	100	14
Phase 1	green																															
Phase 1	yellow	4	0%	0	0%	0	4	0%	4	70%	0	4	27%	100	4	12%	0	4	0%	0	0	0	0	0	0	4	0%	0	4	0%	0	4
Phase 1	red	52	0%	0	70	69%	0	55	16%	0	63	100%	0	57	79%	0	56	100%	0	58	0%	0	68	72%	0	57	61%	0	56	96%	0	53
Phase 1	termination	gap-out																														

Average Green Time (sec)	Average Green Occupancy (%)	Average Used Green (sec)	Average Available Green (sec)	Average Phase Utilization (%)	Degree of Saturation	Average Phase Demand (% time)	M
7.5	64%	6.30	14.5	43.0%	<div style="width: 43%;"></div>	9.0%	10
23.7	67%	15.20	23.7	67.0%	<div style="width: 67%;"></div>	21.7%	20
9.0	87%	7.48	9.3	85.3%	<div style="width: 85%;"></div>	10.6%	10
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2.6	37%	1.99	8.5	28.2%	<div style="width: 28%;"></div>	2.8%	10
30.3	59%	17.15	30.3	59.2%	<div style="width: 59%;"></div>	24.5%	20
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18.3	78%	13.71	22.1	66.3%	<div style="width: 66%;"></div>	19.5%	15



Cyclic occupancy profiles → Statistical profile



Example shows need to move offset so green corresponds with traffic earlier in cycle



“statistical” flow profile

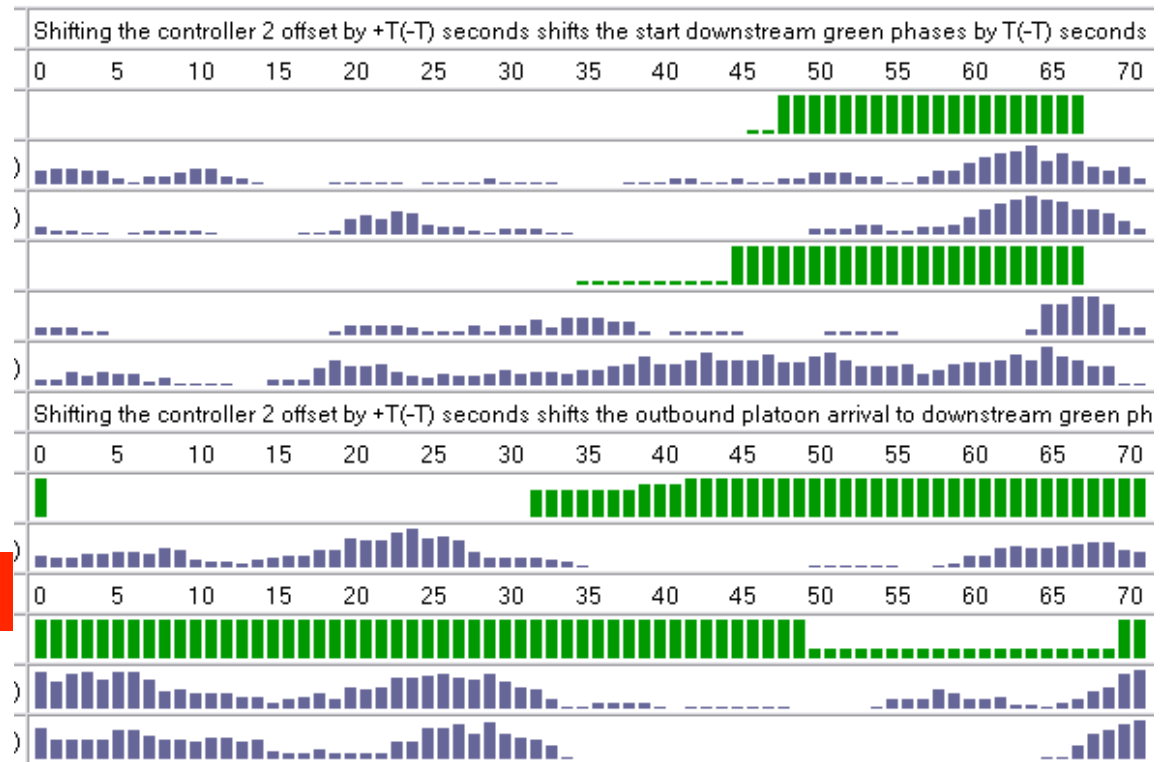


Progression Performance → Offset tuning

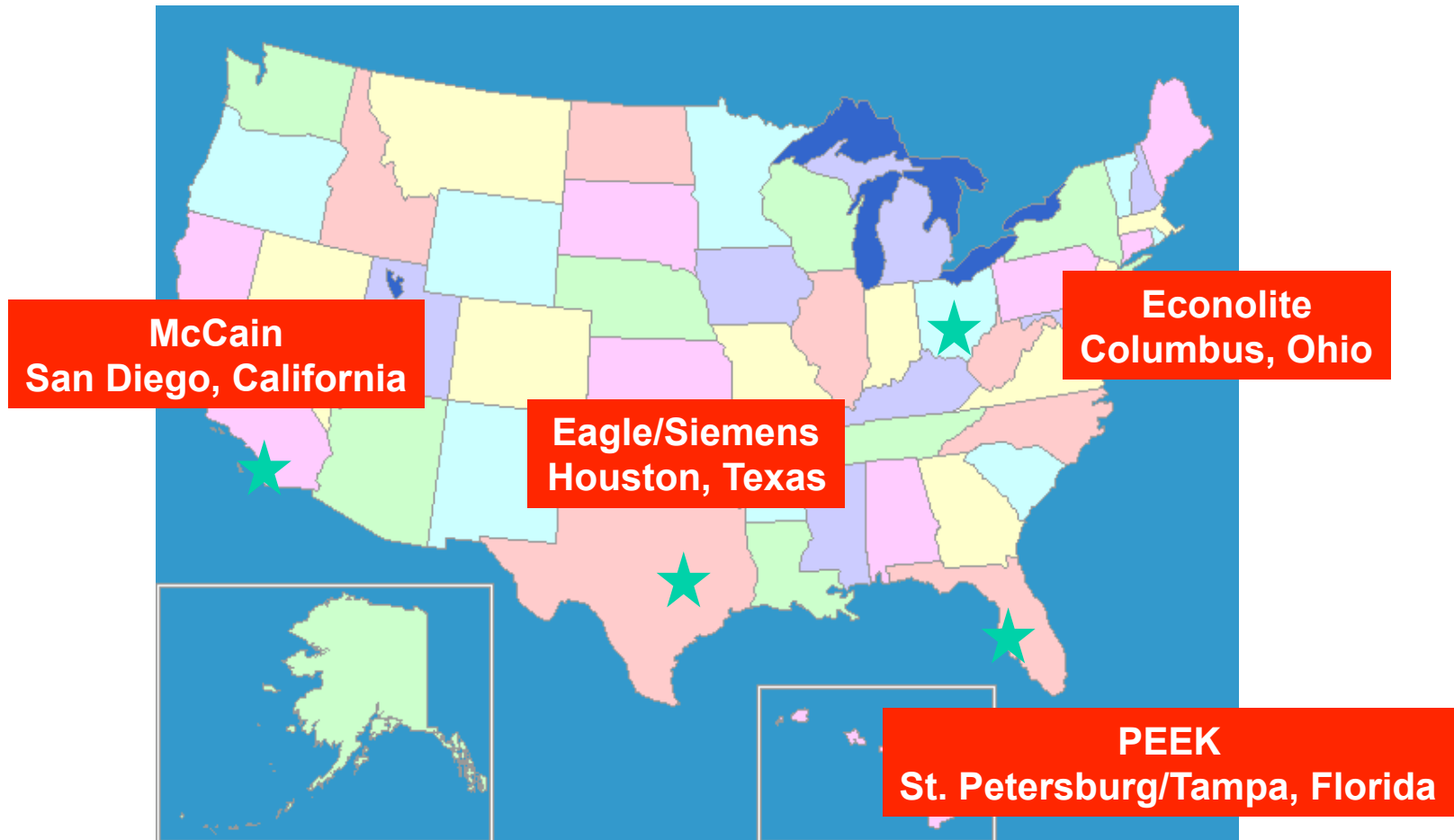
- Performance measure for offsets → “capture efficiency”
- Shift offsets small amount
- Constrain changes within user-configurable bounds

Inbound

Outbound



Field trials

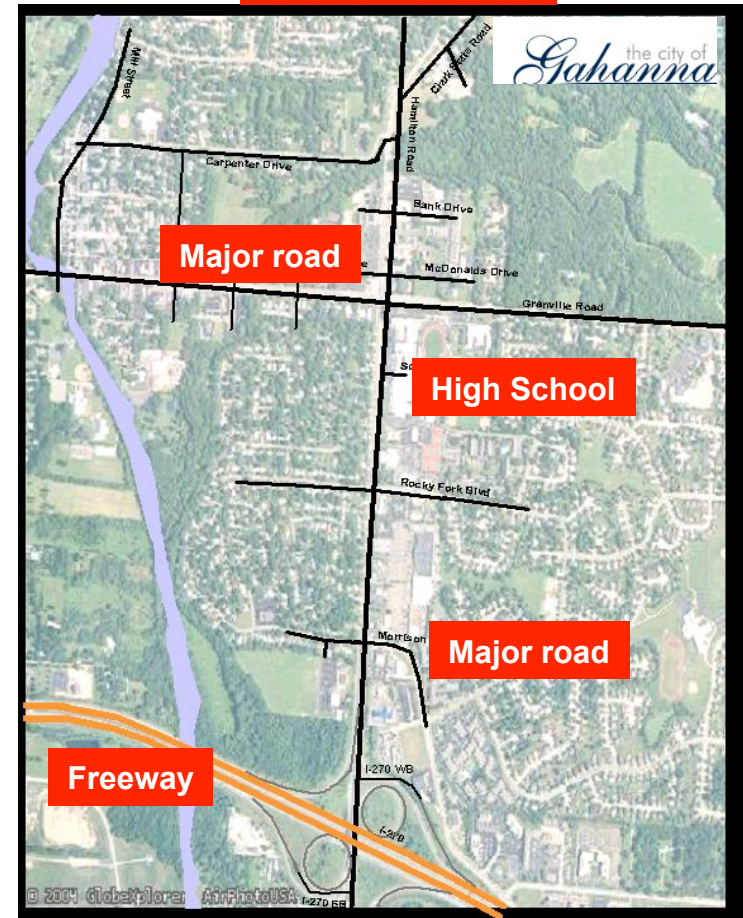


Field trial – Columbus, Ohio

- Early “lessons learned”
 - Communications integrity
 - Detector configuration
 - Separate channels per lane
 - Remote configuration capability
 - Details, details



Construction zone



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Future

- Field studies “before and after” results (TRB 2006)
 - Analysis/comparison of ACS-Lite performance data with traditionally collected data
- Algorithms enhancements (2006-2008):
 - Long-term parameter adjustment
 - Seasonal baseline parameters
 - TOD schedule switch points
 - Cycle time tuning
 - Selection of transition method
 - Weather-responsive

