



# ACS-Lite FHWA adaptive control for closed-loop systems

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**2<sup>nd</sup> Baltimore Regional Traffic Signal Form**

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**Maryland, USA**



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



**PURDUE**  
UNIVERSITY



**EAGLE** Traffic Control Systems



Sabra, Wang & Associates, Inc.

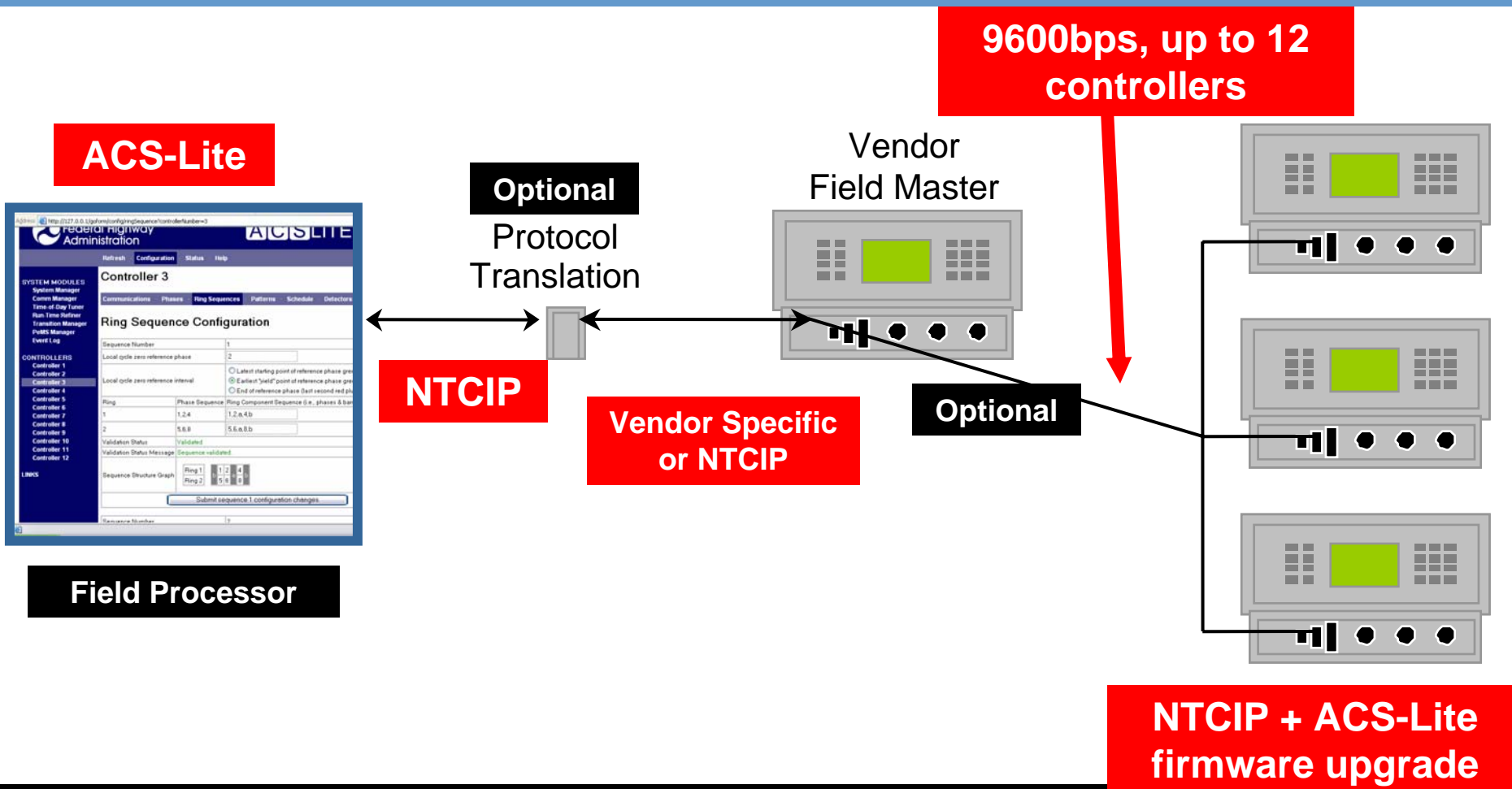


**ITT Industries**  
*Engineered for life*



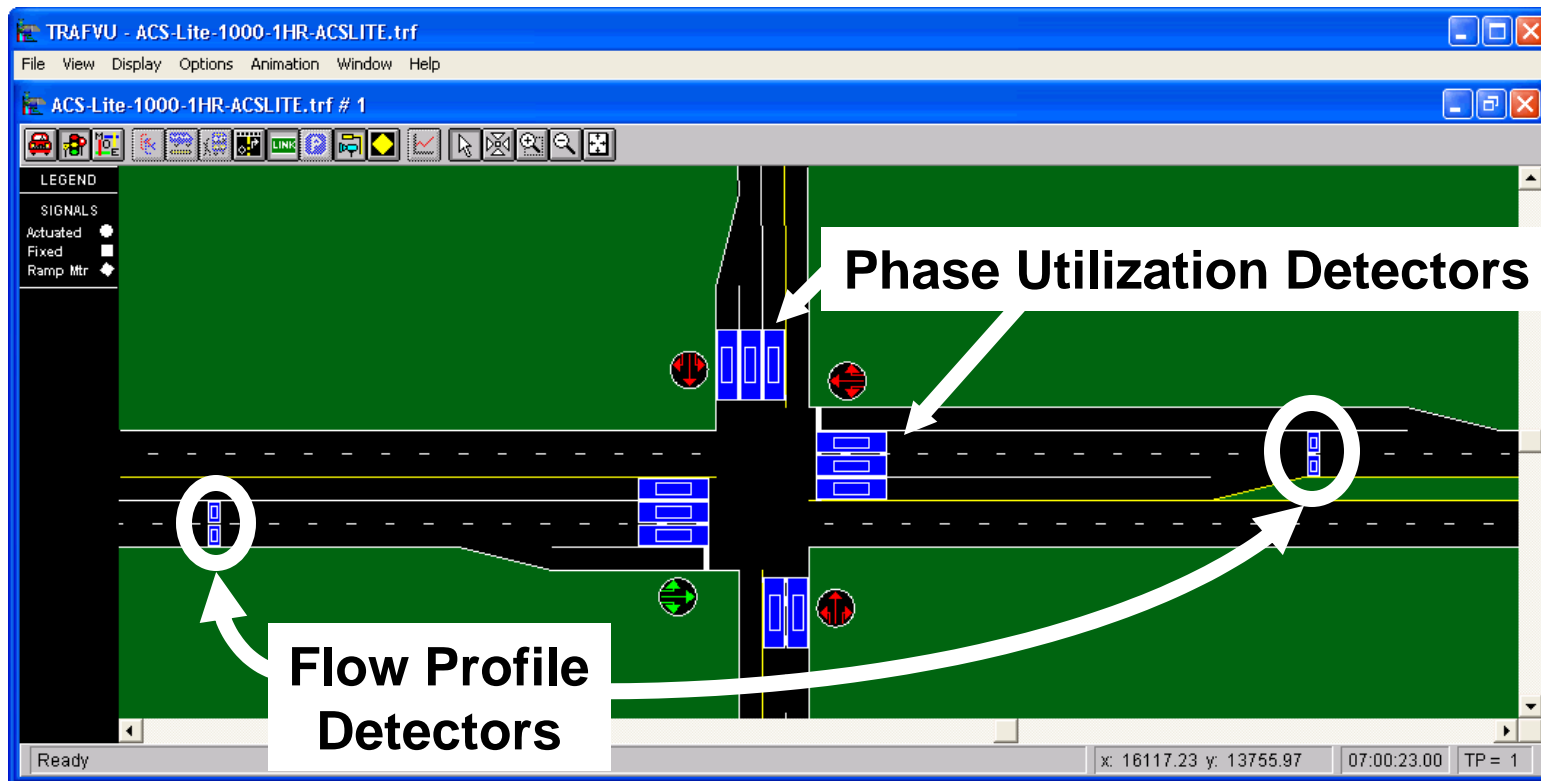
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# System Architecture



# 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



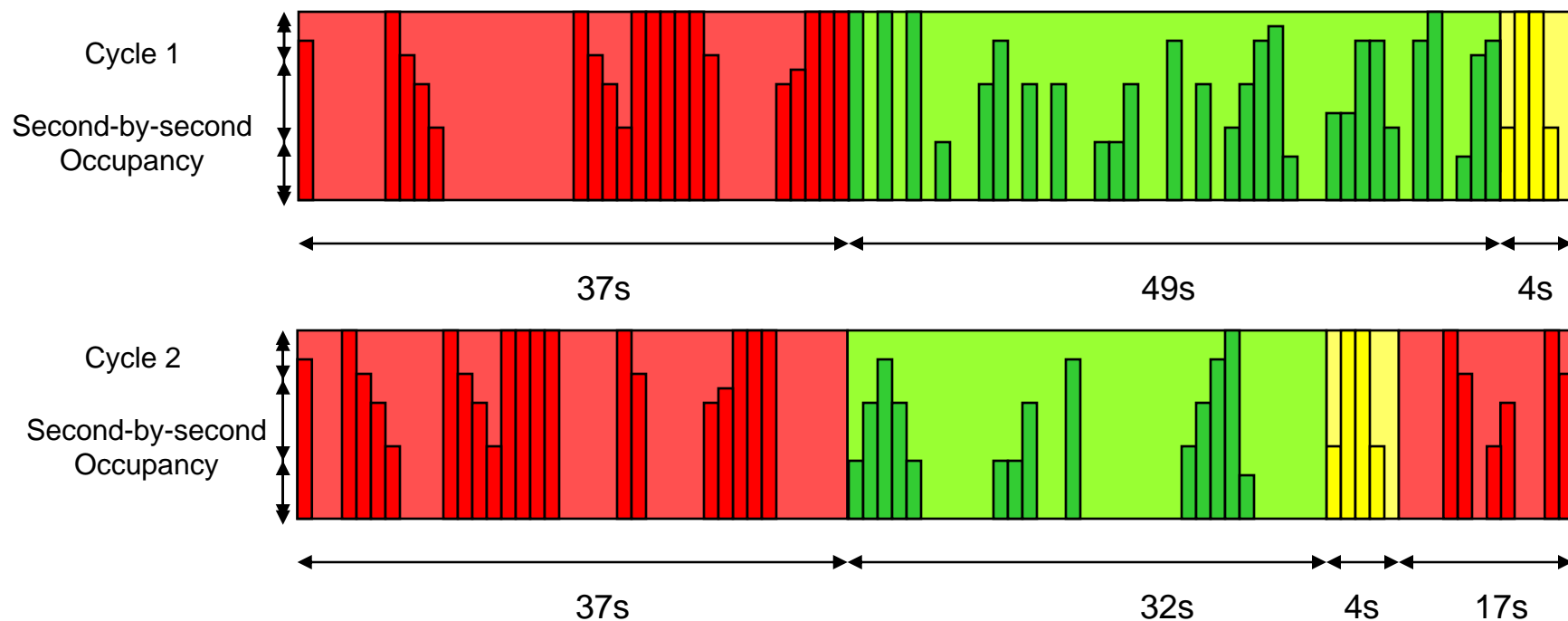
# ACS-Lite NTCIP firmware upgrade

- 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



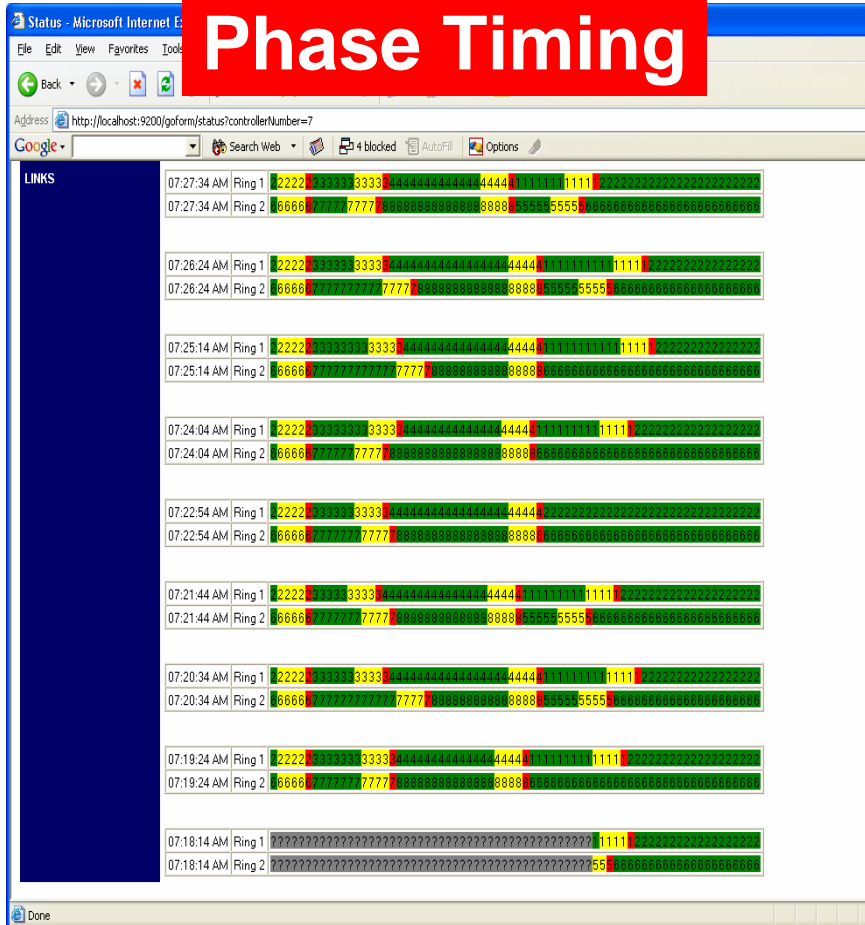
# Occupancy per phase interval

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

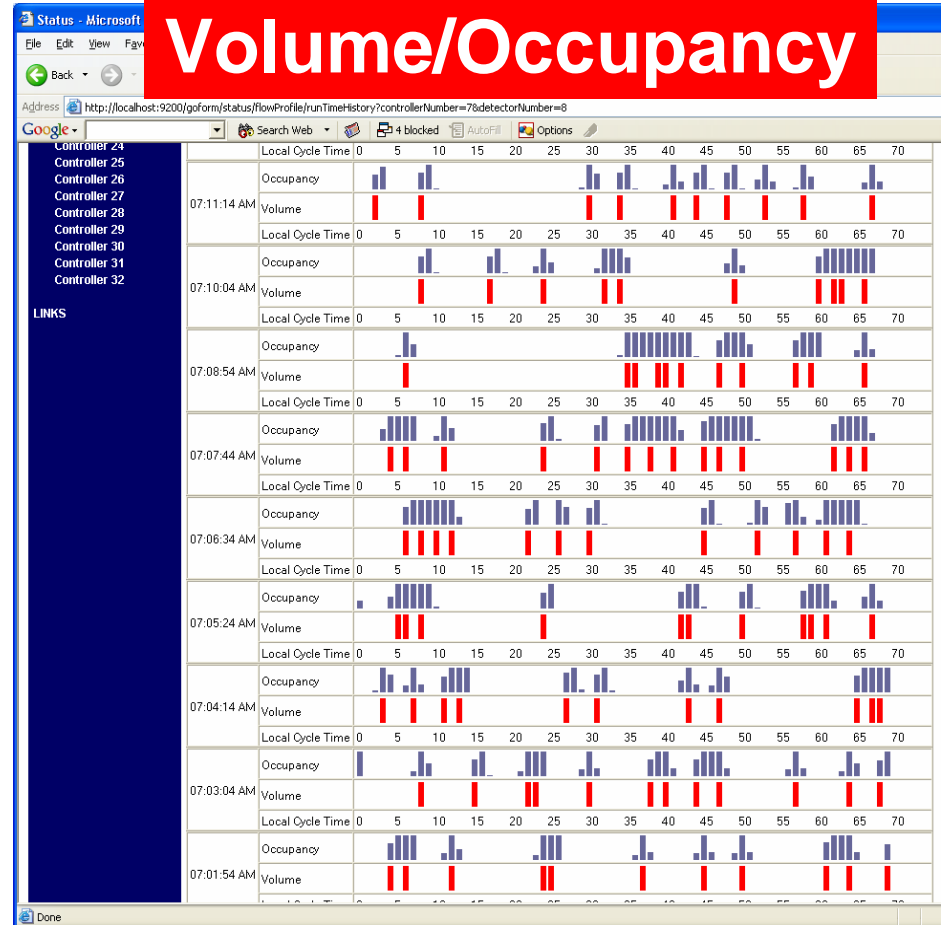


# Cycle-by-cycle Data

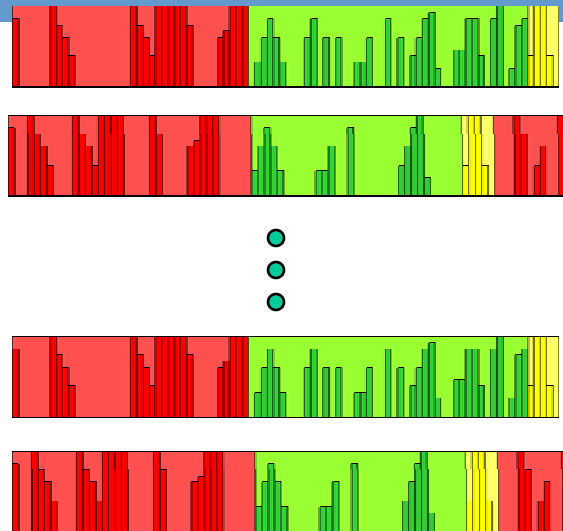
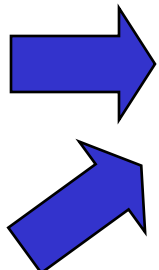
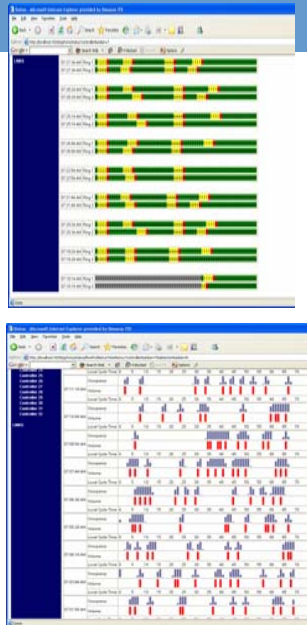
## Phase Timing



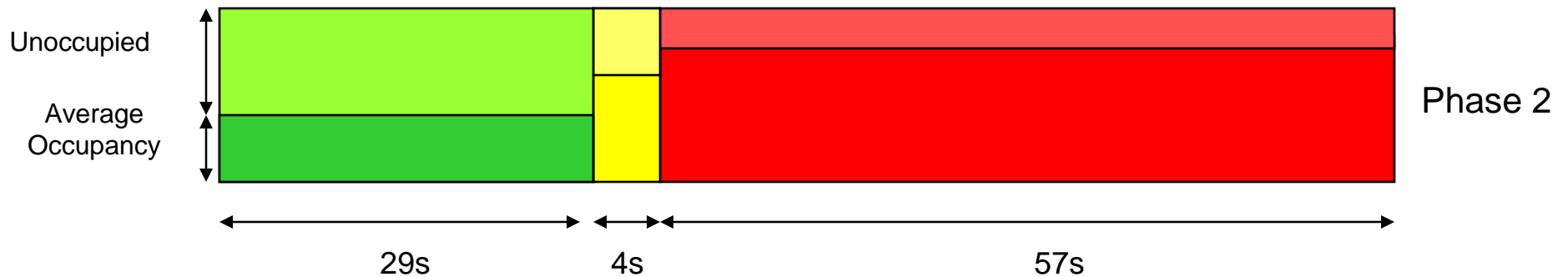
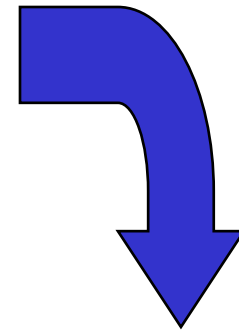
## Volume/Occupancy



# 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

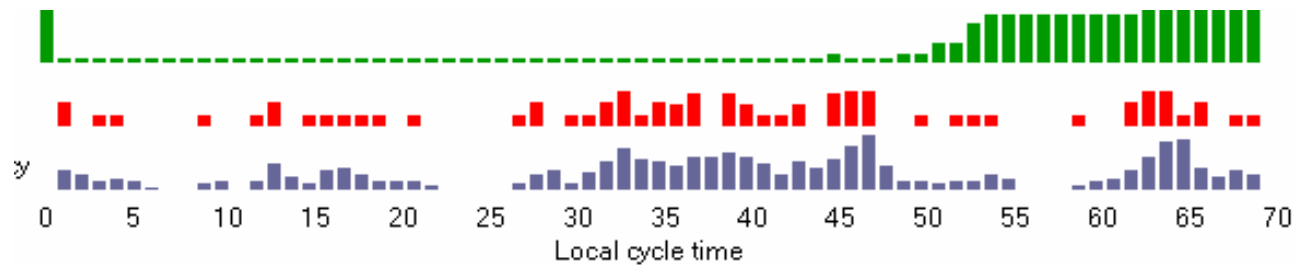
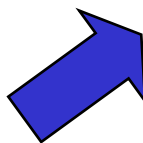
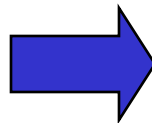
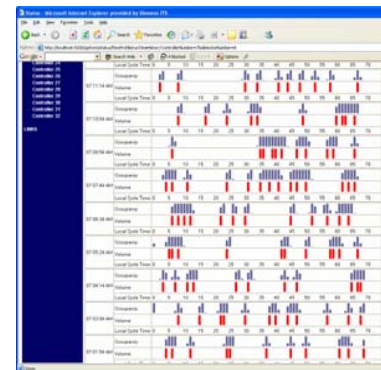
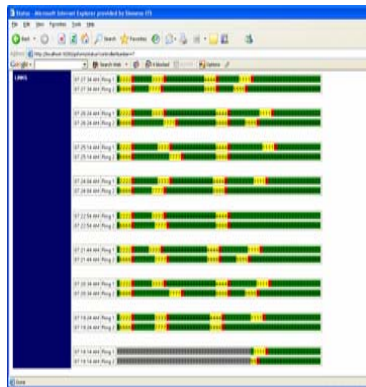
Phase Number	Number of Observations	Gap-outs	Max-outs	Force-offs	Omits/Skips	Termination Timeline	Average Green Time	Average Green Occupancy	Average Used Green	Average Available Green	Average Phase Utilization	Degree of Saturation	Average Phase Demand	Minimum Split	Current Split	Maximum Split
1	12 (100%)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

Ring 1 (1) 1018025 (+) -608 (2) 202185 (+) -18014 (3) 1013025 (+) -30012 (4) 152030 (+) -50010  
Ring 2 (5) 1018025 (+) 08015 (6) 202185 (+) -7008 (7) 101725 (+) -18014 (8) 151830 (+) -50010  
Barrier Groups (min) 303745 (max) 253340 (min) 303745 (max) 253340

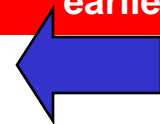
Average Green Time (sec)	Average Green Occupancy (%)	Average Used Green (sec)	Average Available Green (sec)	Average Phase Utilization (%)	Degree of Saturation	Average Phase Demand (% time)
7.5	64%	6.30	14.5	43.0%		9.0% 10
23.7	67%	15.20	23.7	67.0%		21.7% 20
9.0	87%	7.48	9.3	85.3%		10.6% 10
10.5	42%	4.81	19.2	31.6%		6.8% 15
2.6	37%	1.99	8.5	28.2%		2.8% 10
30.3	59%	17.15	30.3	59.2%		24.5% 20
3.3	35%	2.56	12.0	21.3%		3.6% 10
18.3	78%	13.71	22.1	66.3%		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**

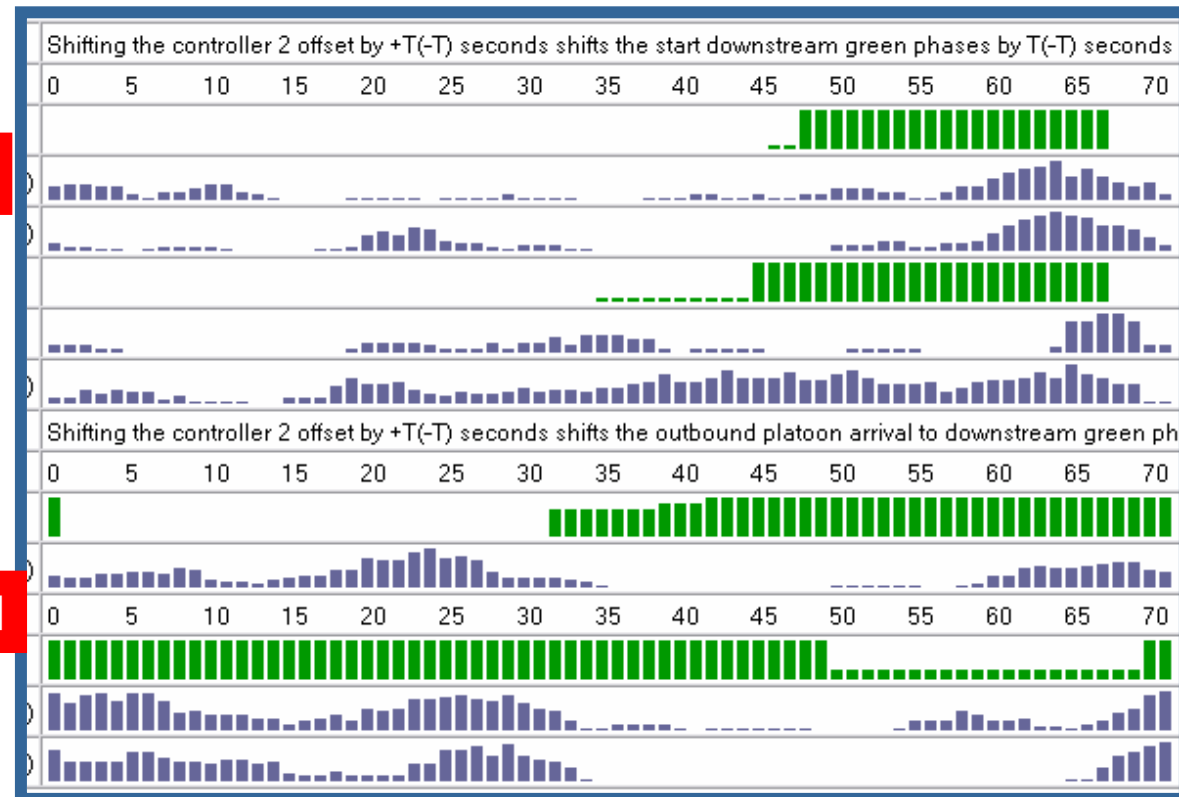


# Progression Performance → Offset tuning

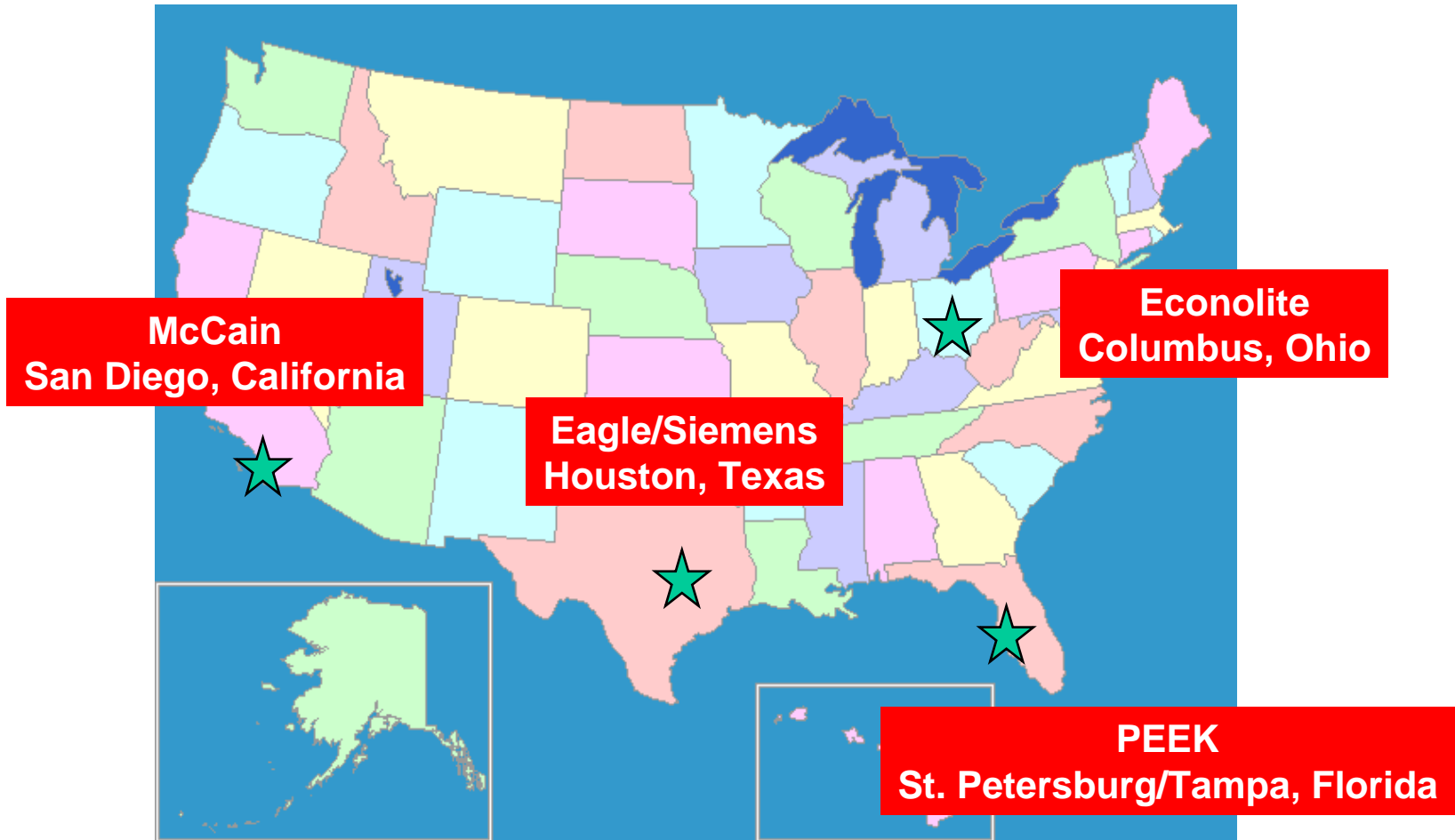
- Performance measure for offsets → “capture efficiency”
- Shift offsets small amount
- Constrain changes within user-configurable bounds

**Inbound**

**Outbound**

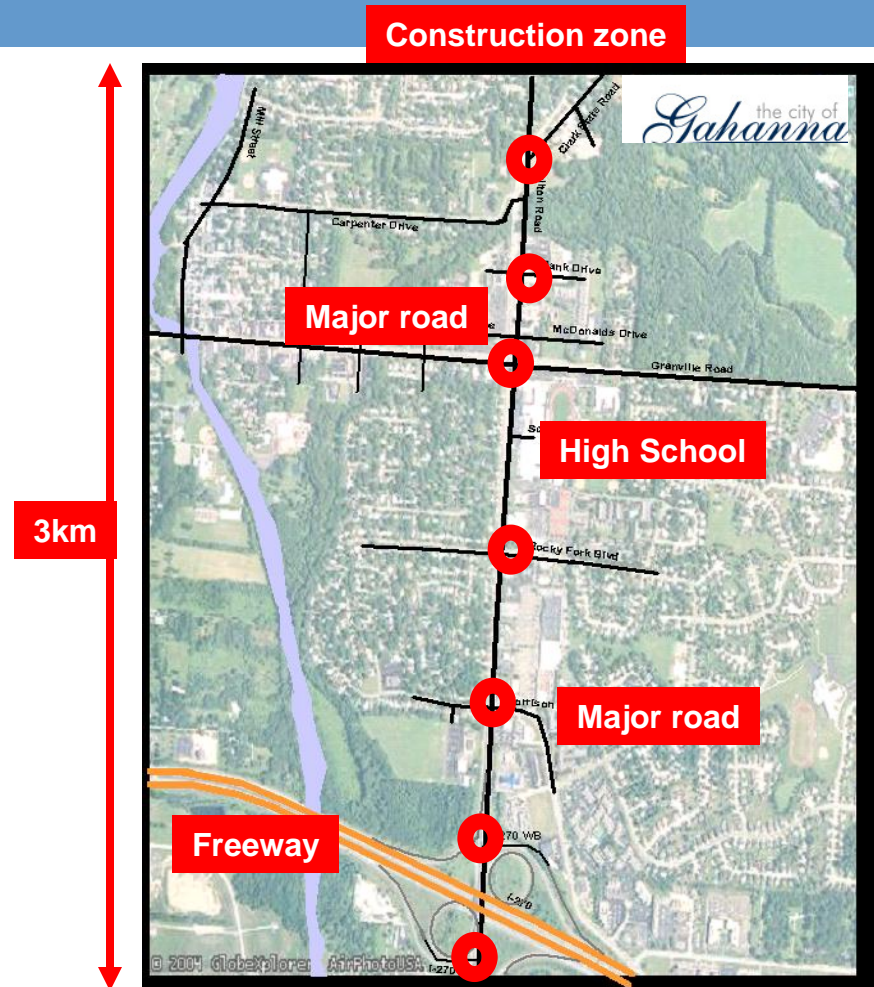


# Field trials



# Field trial – Columbus, Ohio

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



# 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

