ACS Lite Project Overview

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Federal Highway Administration
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Outline

ACS = Adaptive Control Software

- Project goals and status
- What's Lite about ACS Lite?
- ACS-Lite system architecture
- ACS-Lite algorithms overview
- Performance results
- Questions?

FHWA's Motivation for the ACS-Lite Project

- **Limited U.S. deployment** of ACS
  - 8 agencies as of 1999
- FHWA ACS research
  - RHODES, OPAC, RTACL
- ACS survey & ITE roundtable
  - 70% say ACS too costly
  - 40% unconvinced of benefits over TOD/TRPS
  - ACS too sensitive/dependent on communications & detectors
  - Difficult to understand, configure, and maintain
- Closed-loop systems are prevalent in marketplace
  - Can we develop an adaptive solution augmenting existing hardware?

FHWA's ASC-Lite Project Goals

WIDELY DEPLOYABLE adaptive control

- Low cost design
- Leverage existing infrastructure
  - Work with closed-loop systems & standard actuated controllers
  - Standard fully-actuated detector layouts
  - Communications bandwidth & protocols
  - Standard NTCIP interface
  - Field deployable without connection to TMC
- Meet performance expectations

Project Team

U.S. Department of Transportation
Federal Highway Administration

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Project Partners

TSIS/CORSIM integration & FHWA TReL testing

ITT Industries — Charlie Stallard

Controller / Closed-Loop Signal System Vendors

- EAGLE Traffic Control Systems — Mark Hudgins
- ECONOLITE CONTROL PRODUCTS, INC. — Gary Duncan
- McCain — Peter Ragsdale
- PEEK — Ed Bertha

Project Summary

- Started in March 2002
  - Siemens ITS, Purdue, Arizona
  - Upgrade CORSIM (ITT Industries) for NTCIP interface
  - Partnership with NEMA controller manufacturers
    - Eagle, Econolite, McCain, PEEK
  - Focus on arterials in initial phase, networks at a later time
- Status
  - Initial software development complete
  - Initial simulation evaluation complete
  - Initial phase final report available March 2004
- Coming soon
  - Hardware-in-the-loop testing at Turner Fairbank Traffic Research Lab (TReL)
  - Field testing with participating NEMA systems
  - Additional R&D of algorithms and additional components

What’s “Lite” about ACS-Lite?

Effective

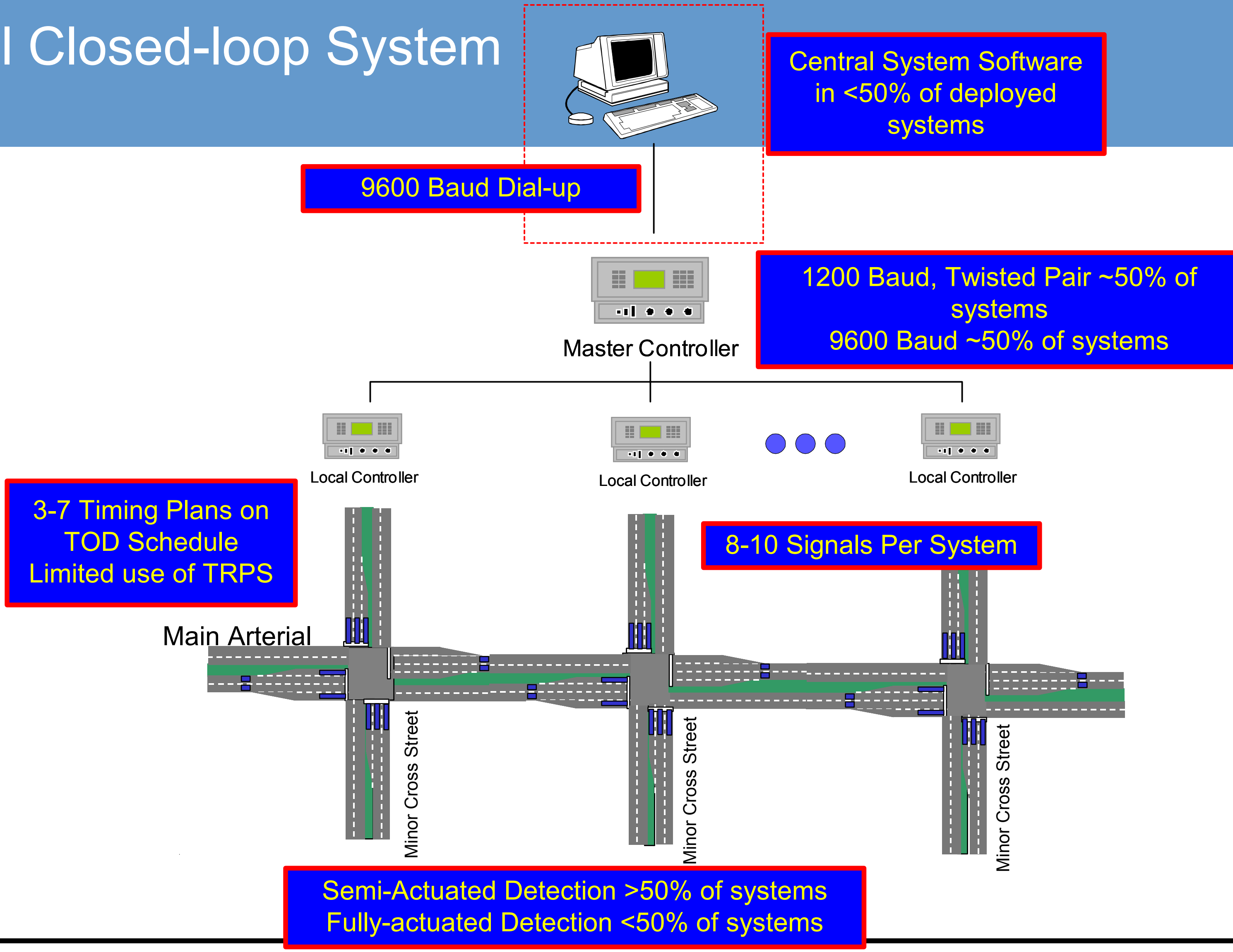
Inexpensive

Compatible

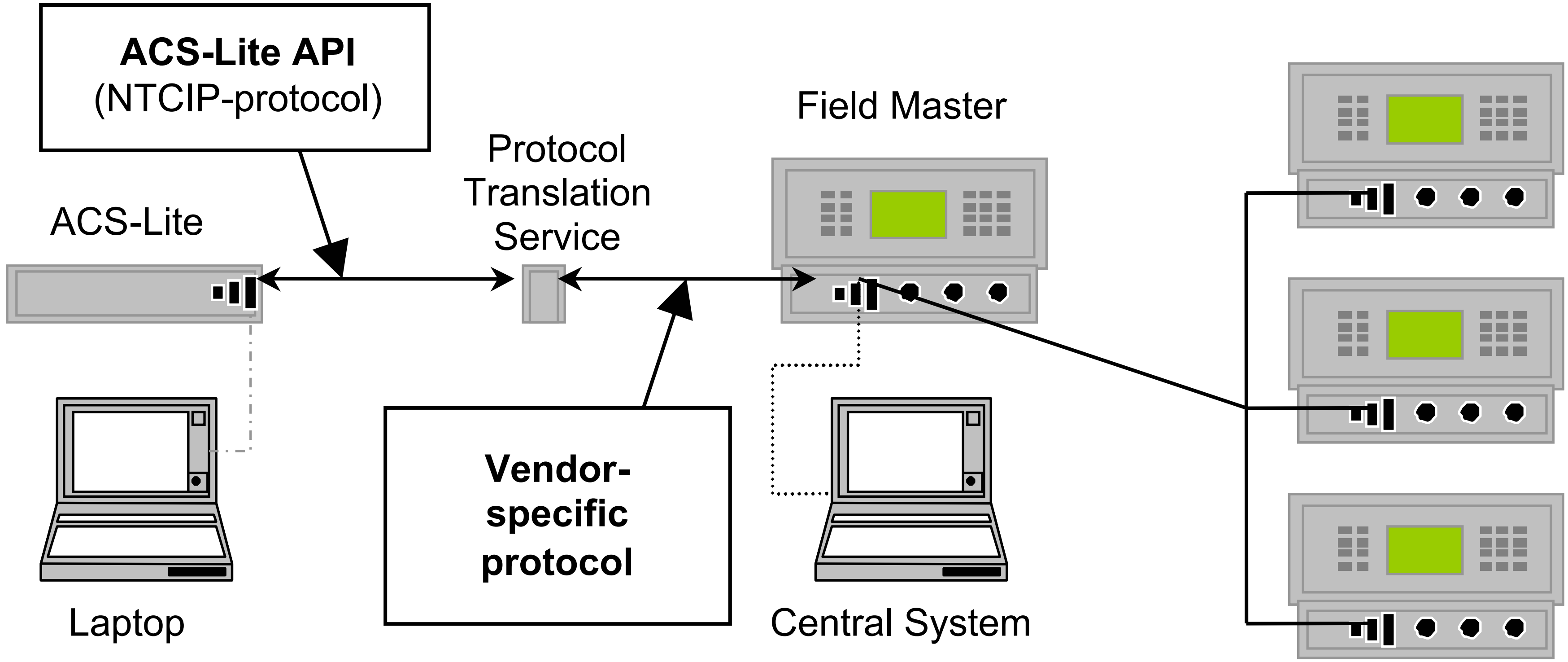
Easy to use

“Low-Hanging Fruit”

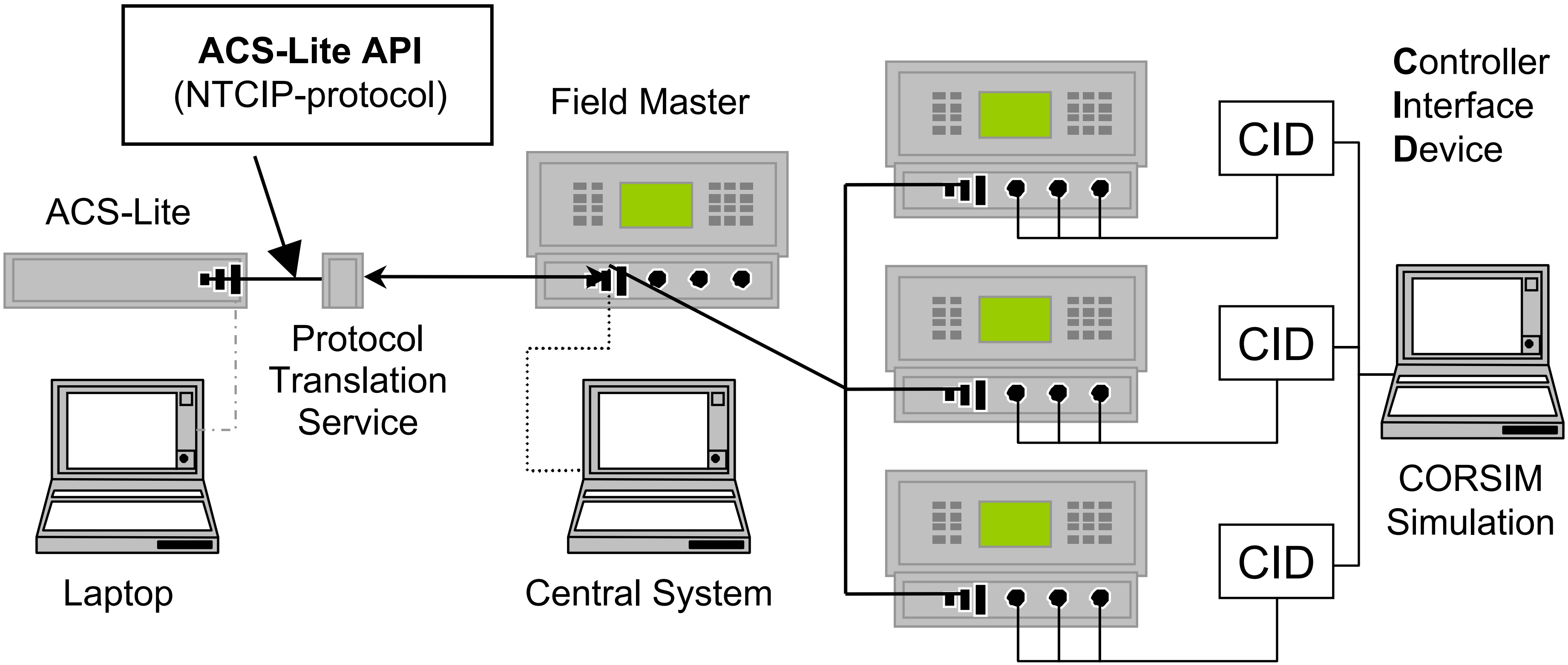
Typical Closed-loop System



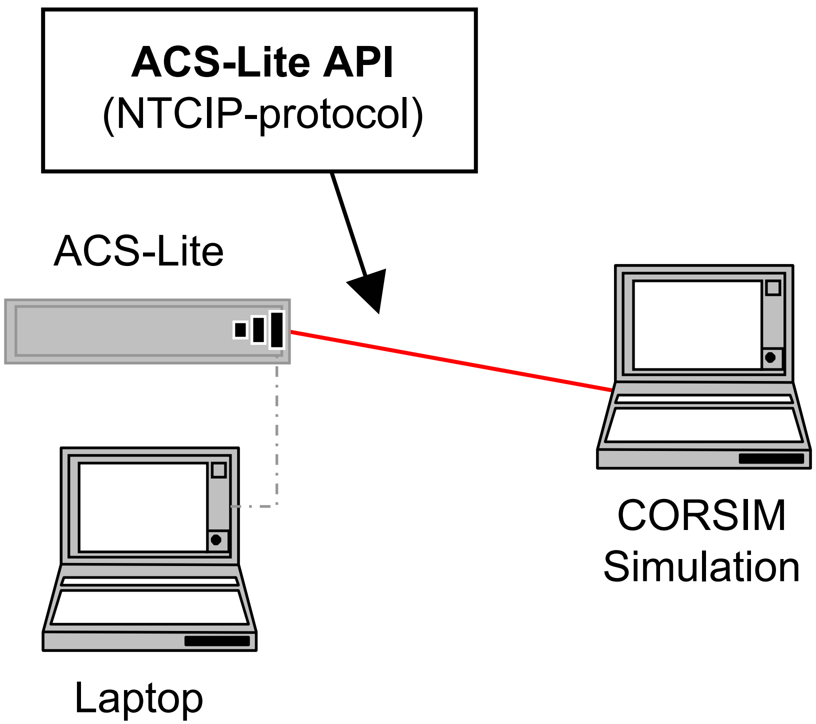
System Architecture

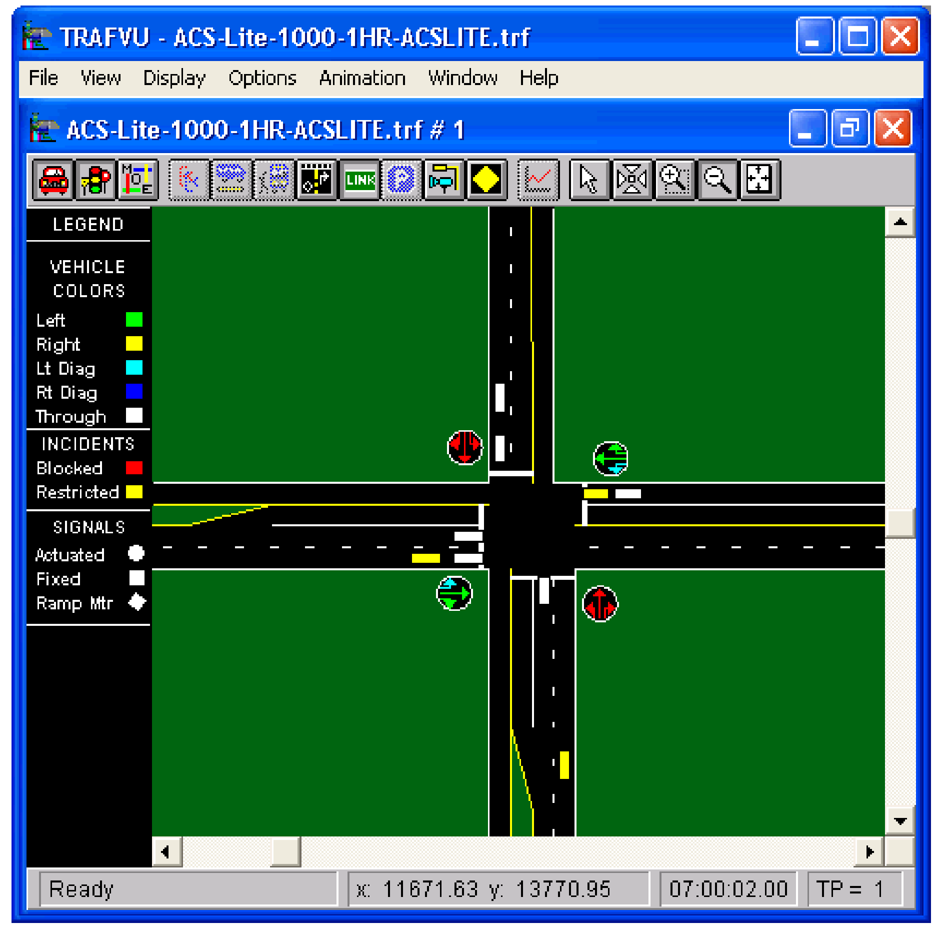


Turner-Fairbank TReL Testing Configuration

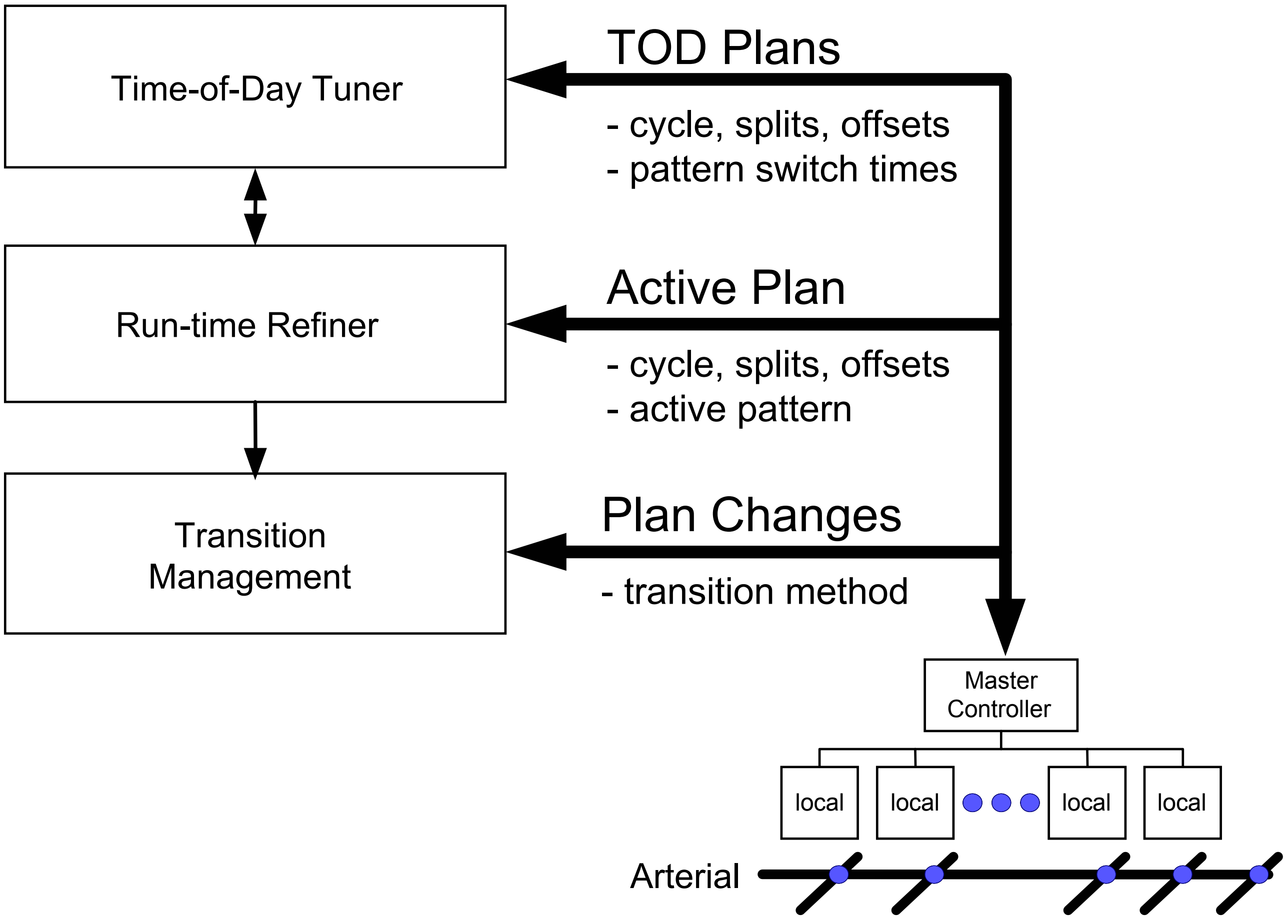


Current Laboratory Configuration

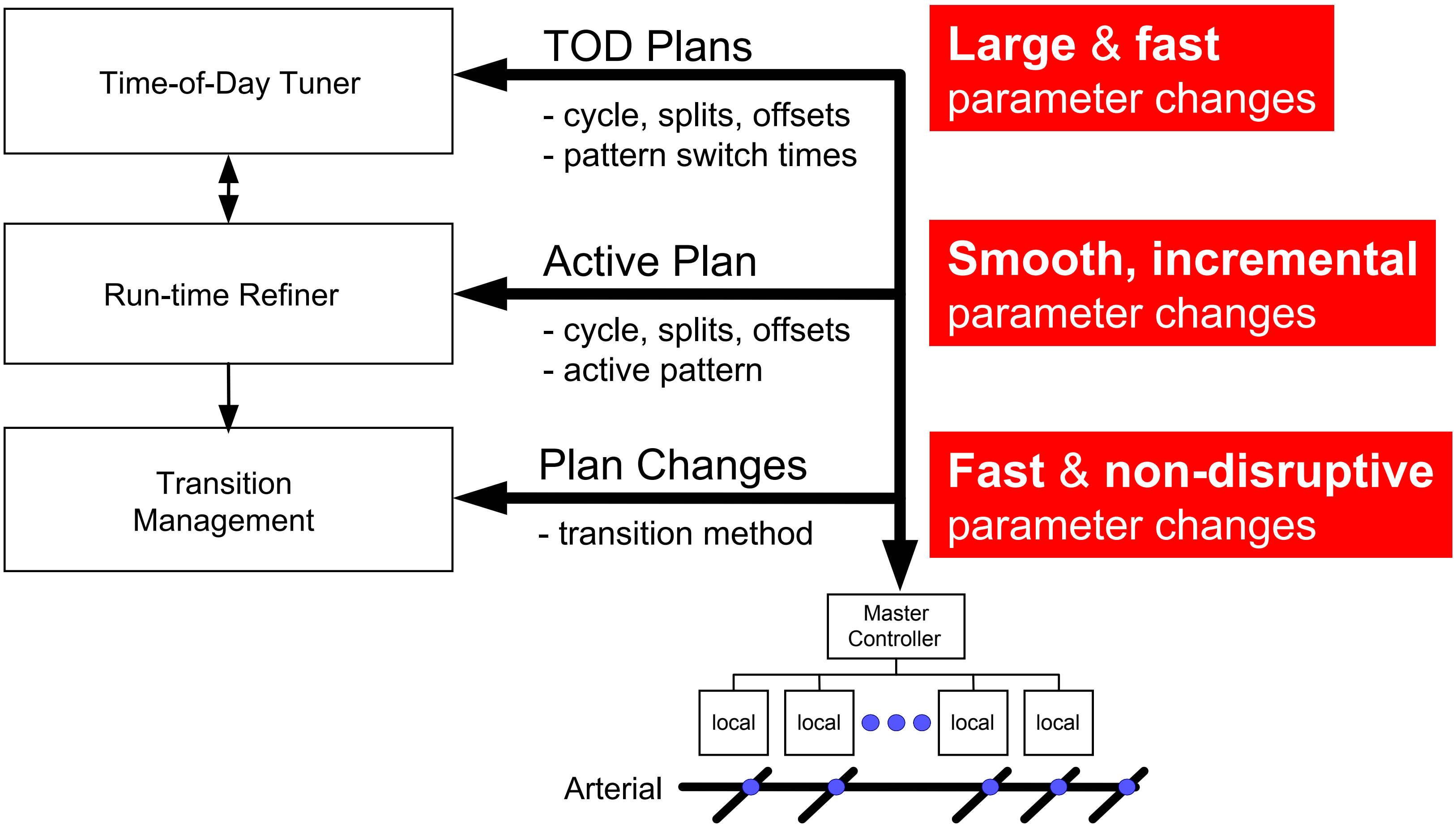




ACS-Lite Algorithms Architecture



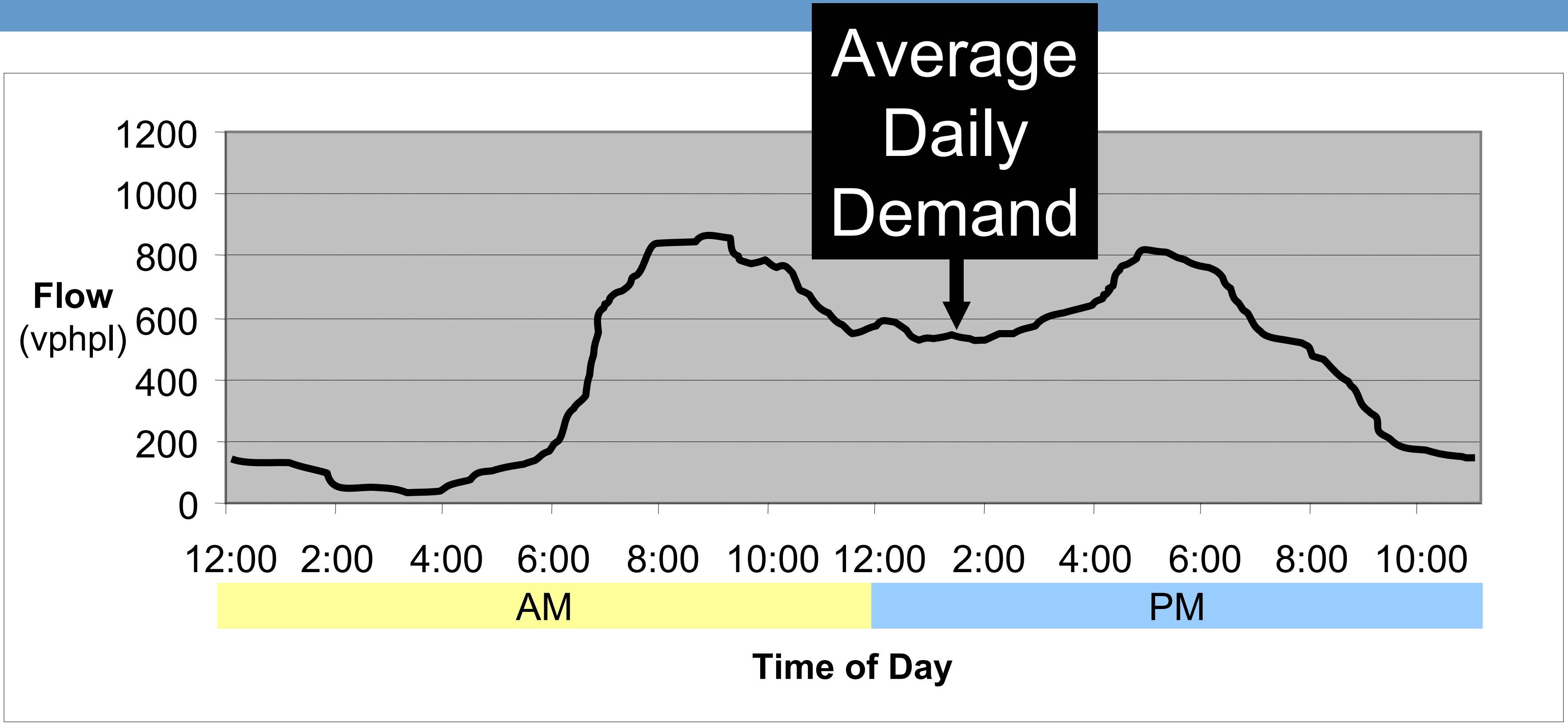
ACS-Lite Algorithms Architecture



Run-Time Refiner

- Adjust active timing plan
  - Cycle (TBD), splits, offsets
  - Small, incremental adjustments (not permanent - TBD)
  - Switch earlier or later to next pattern (TBD)
- Monitor real-time status
  - Detector volume & occupancy
    - Sample every few seconds for cyclic flow profiles
    - Sample during green, yellow, & red intervals for phase utilization
  - Actual phase durations of actuated controller
  - Reasons for termination (max-out, gap-out, etc.)

Illustration of Run-Time Refiner



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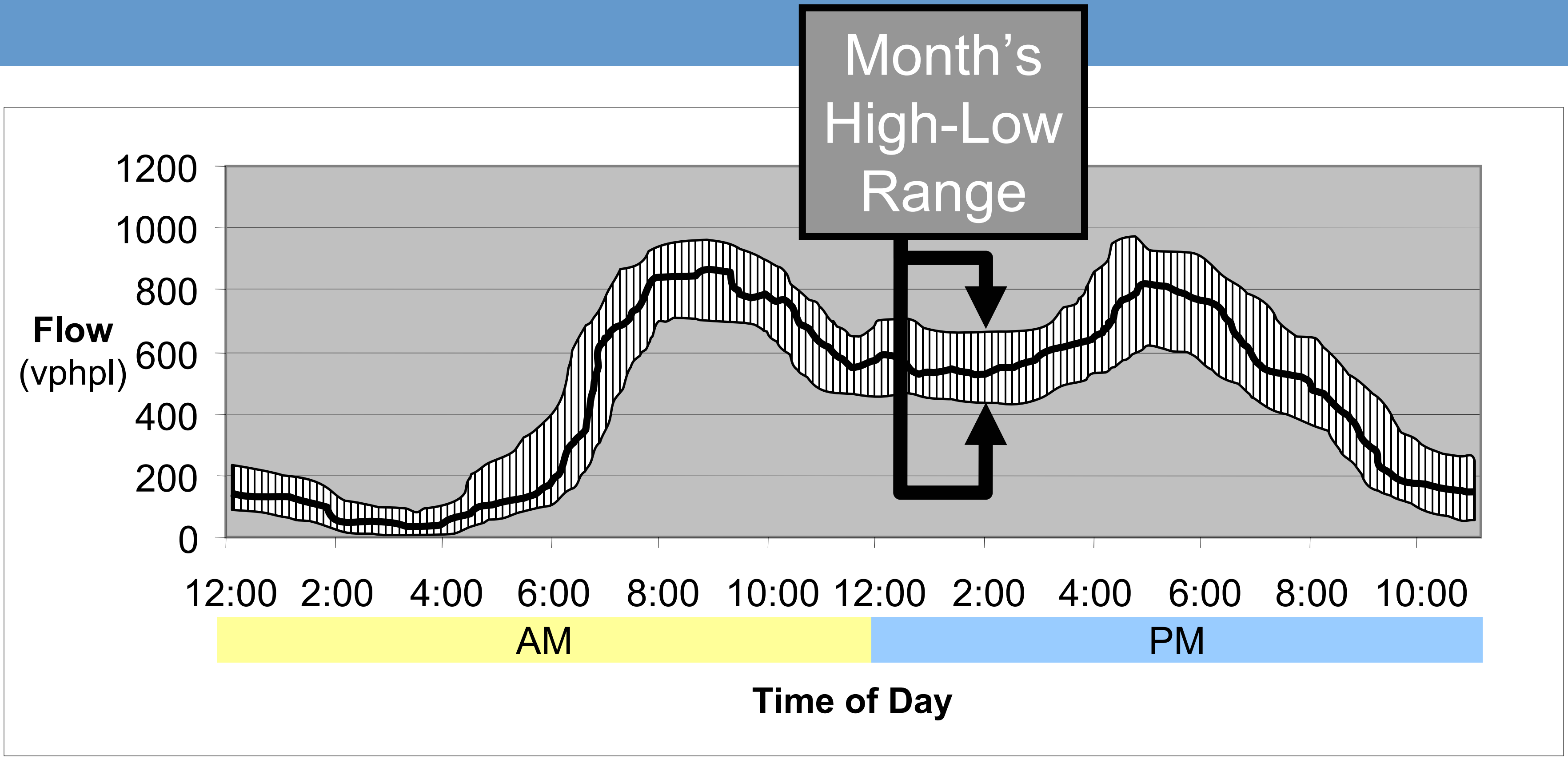

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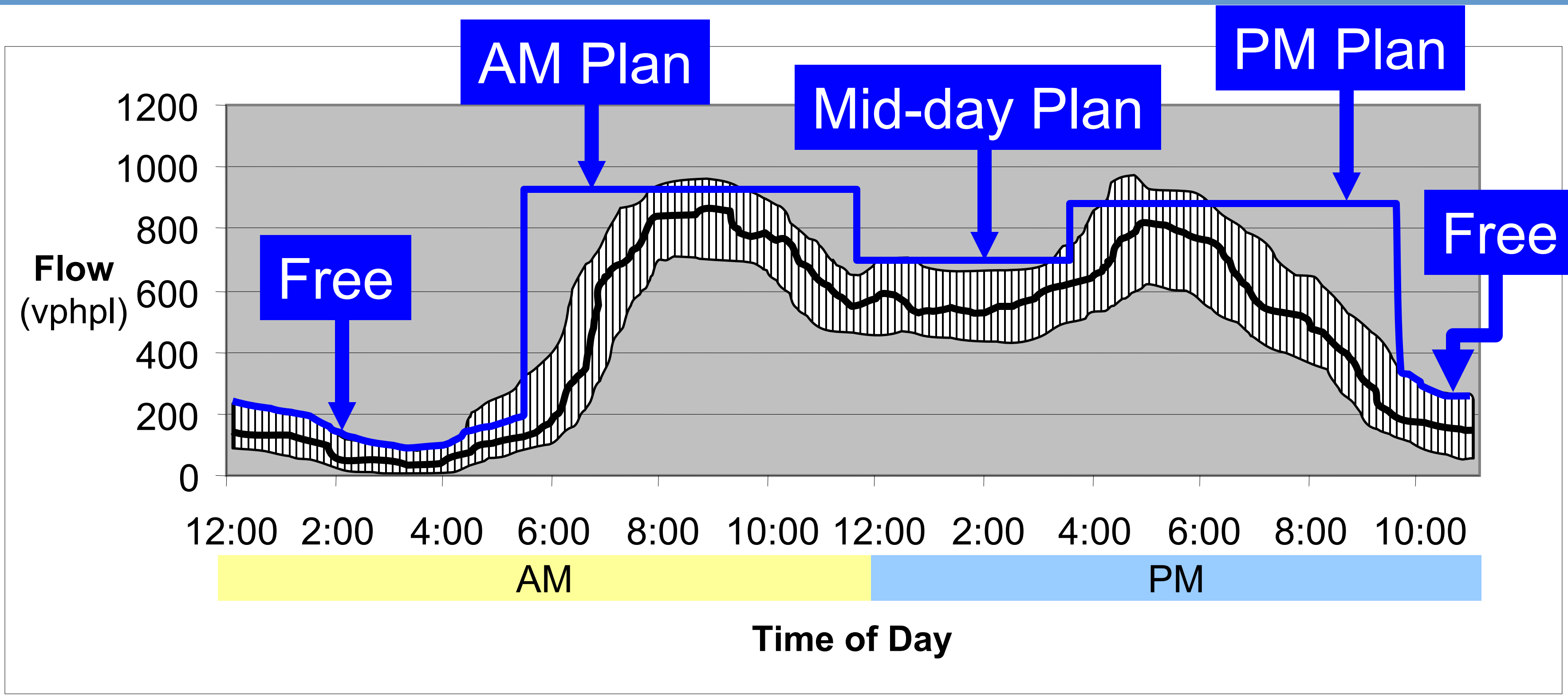

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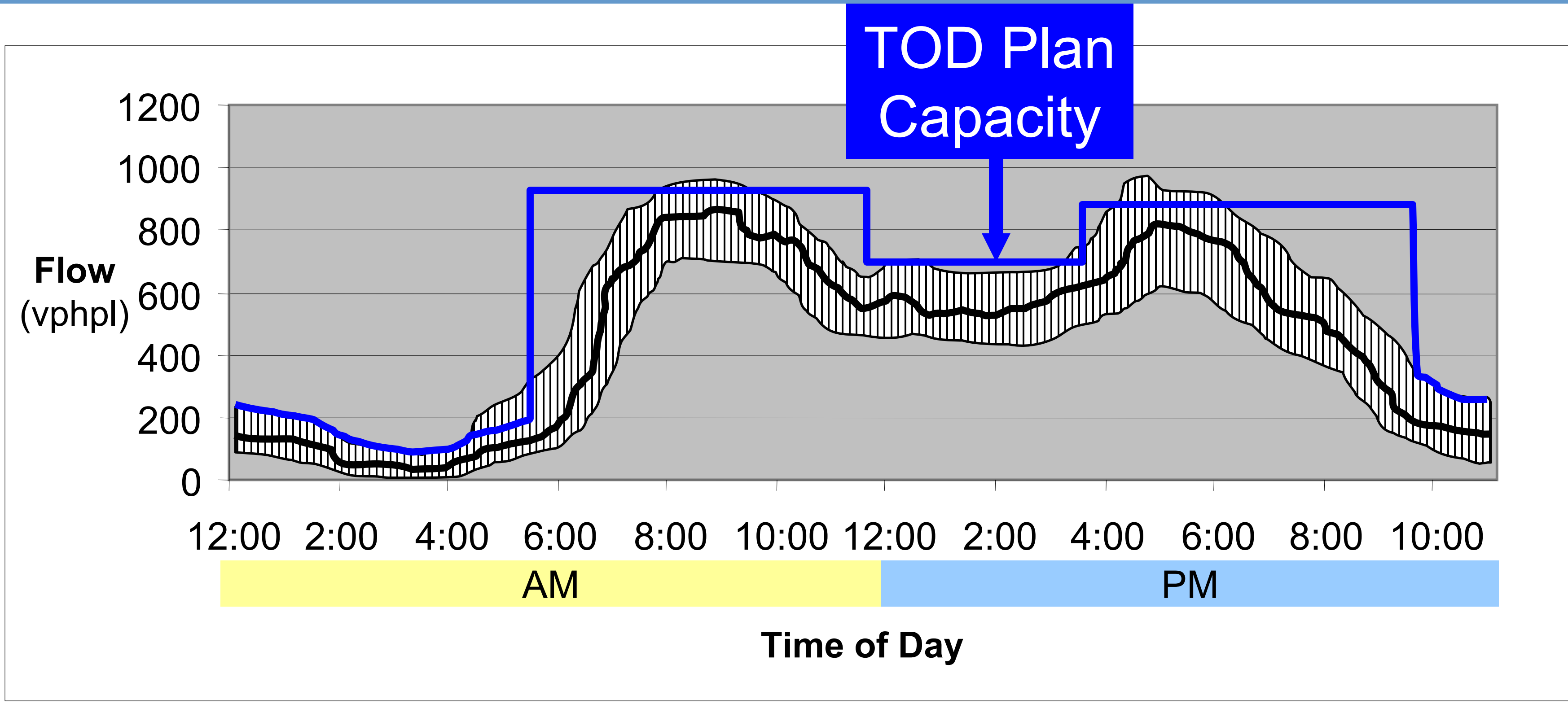

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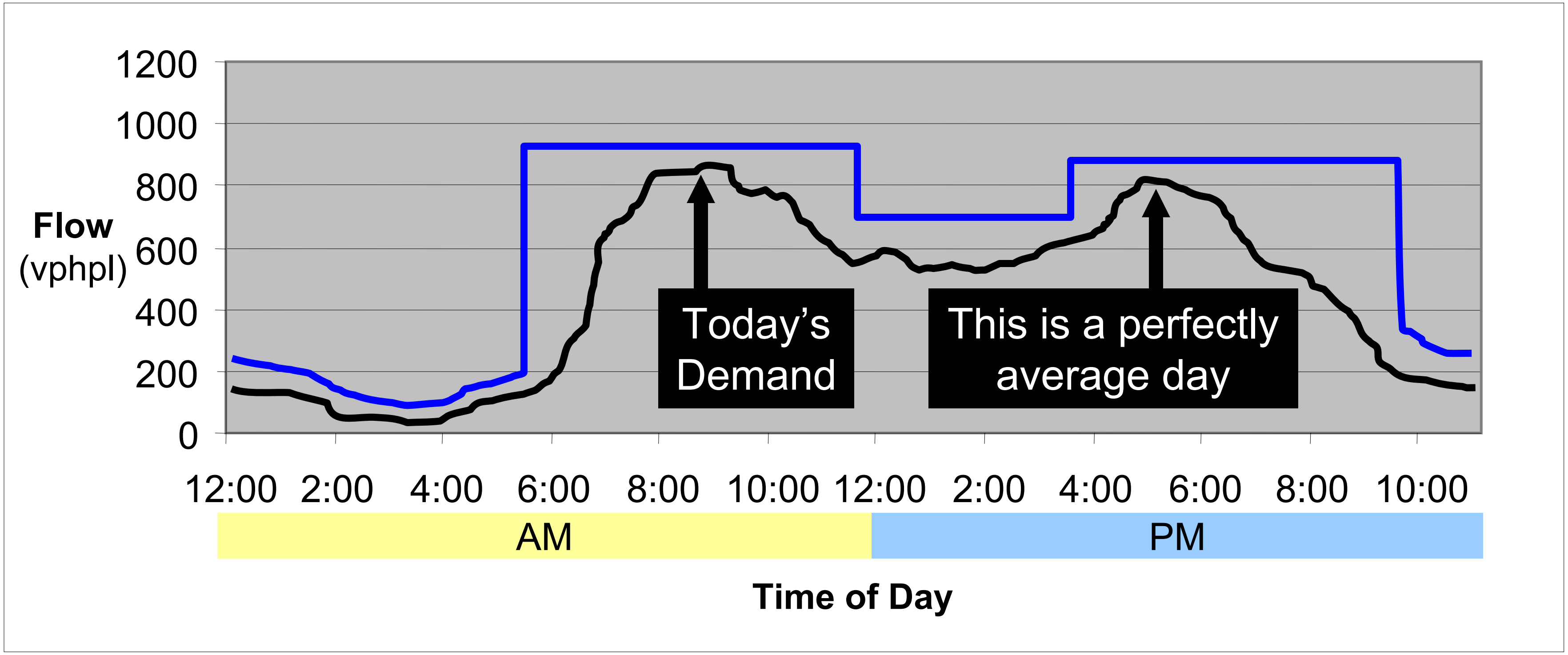

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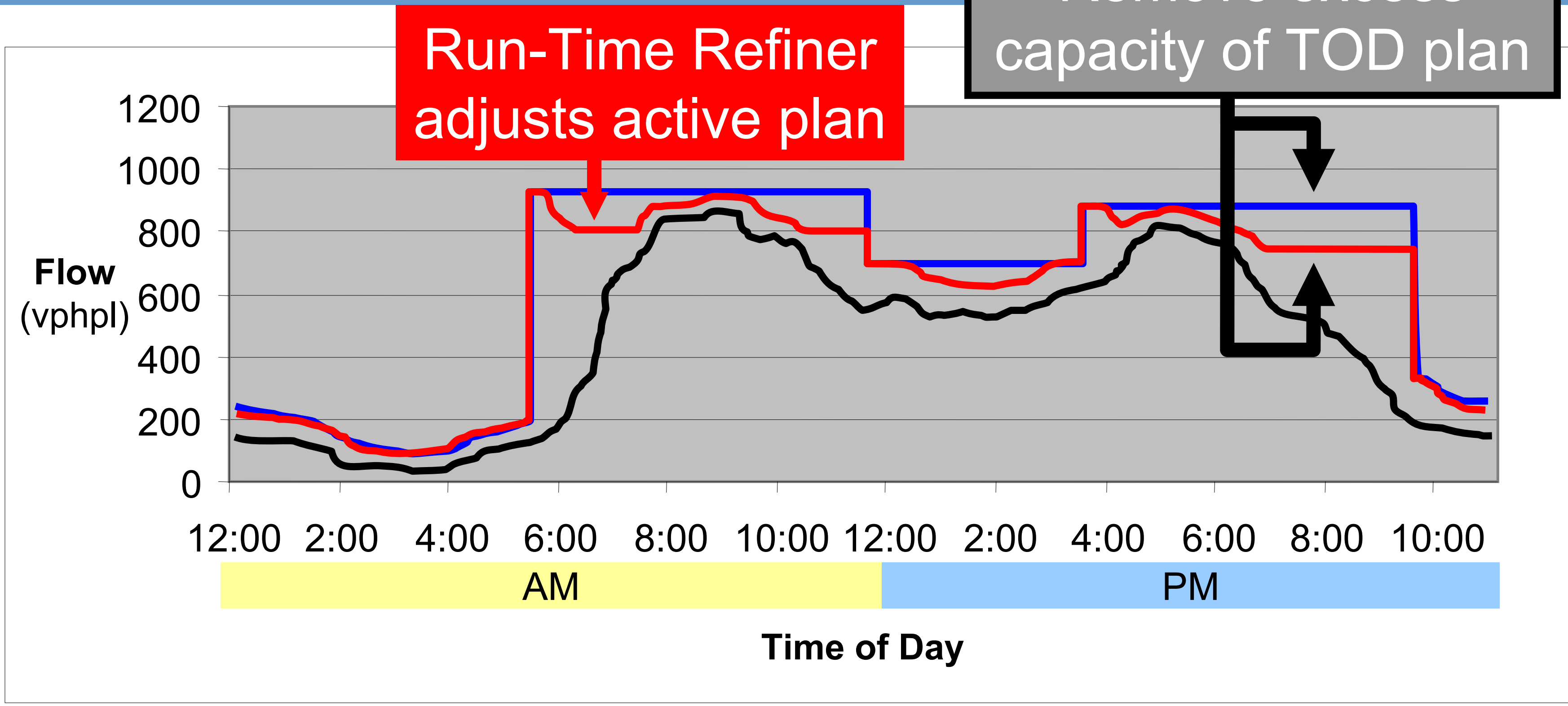

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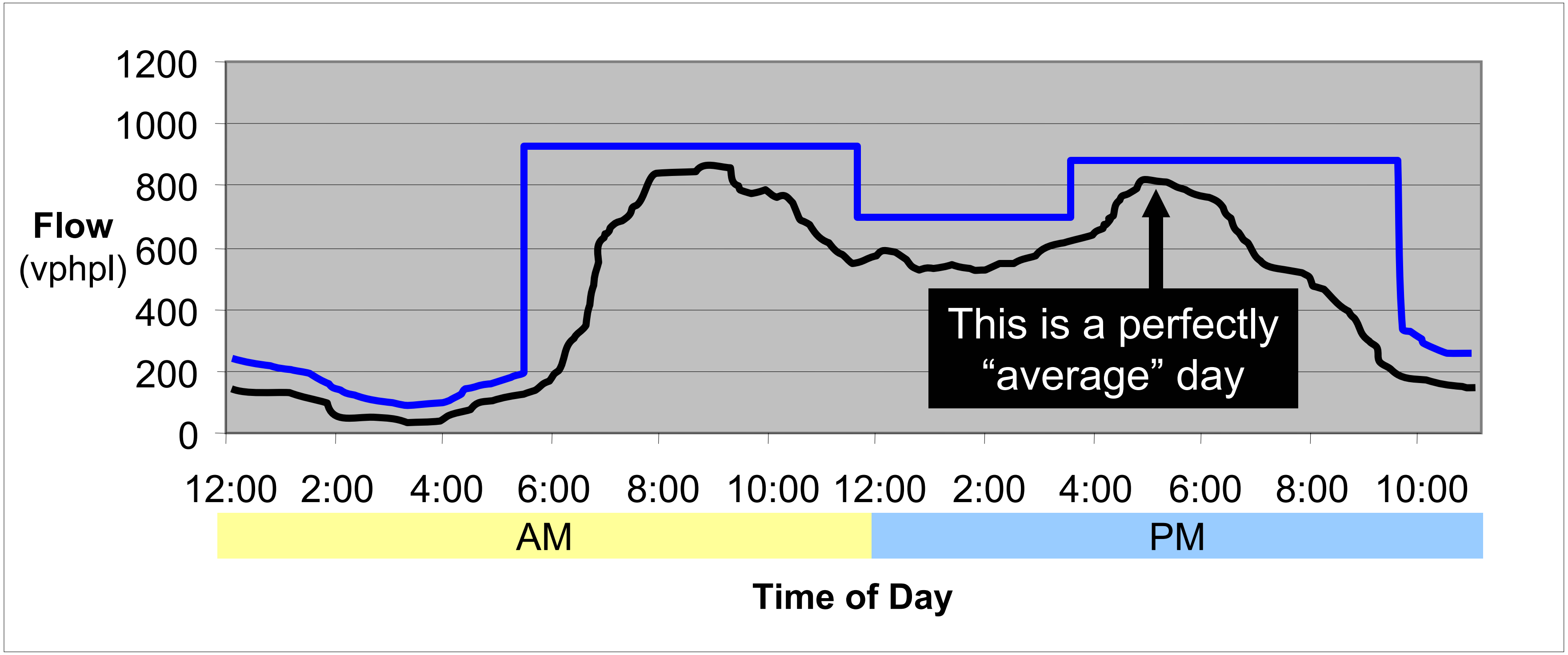

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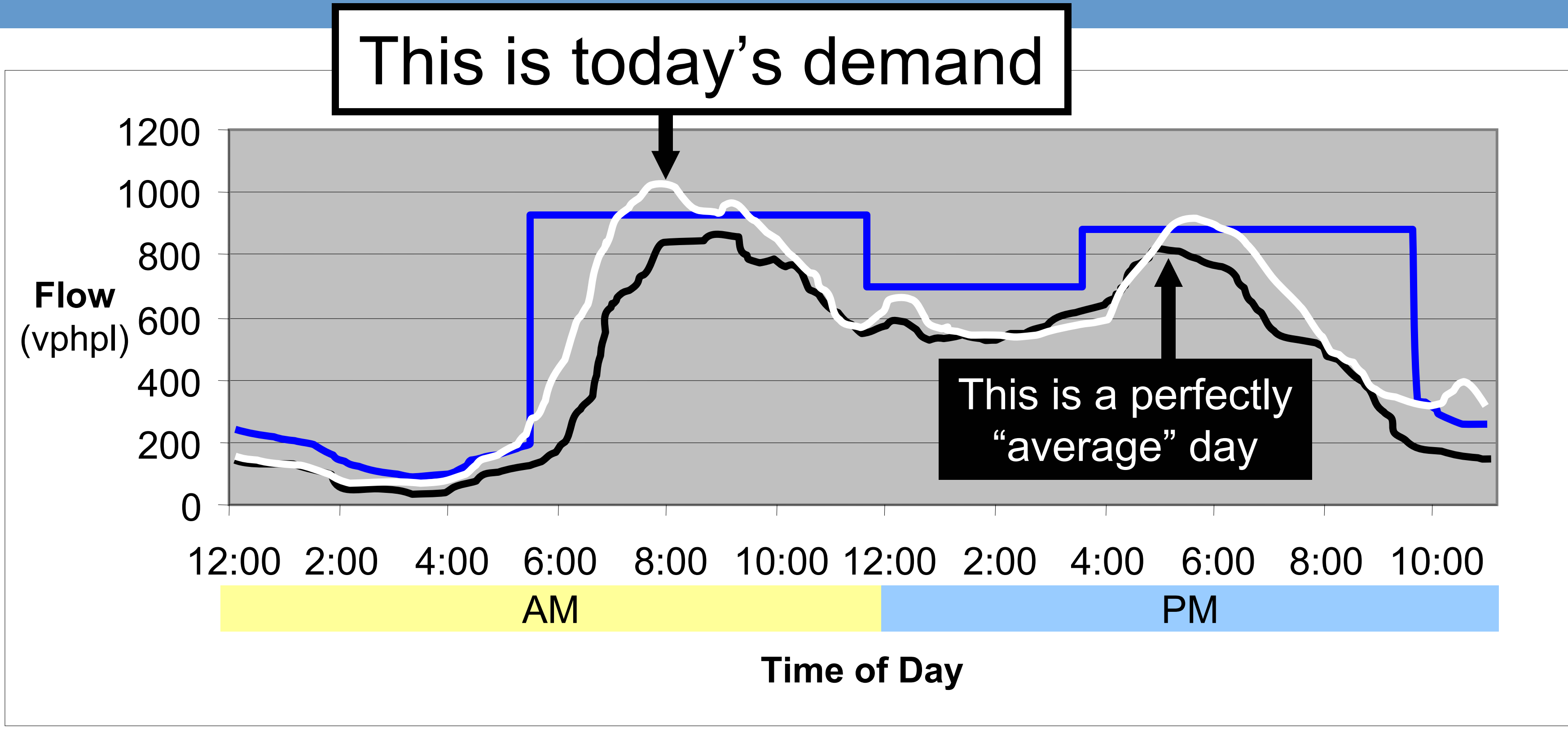
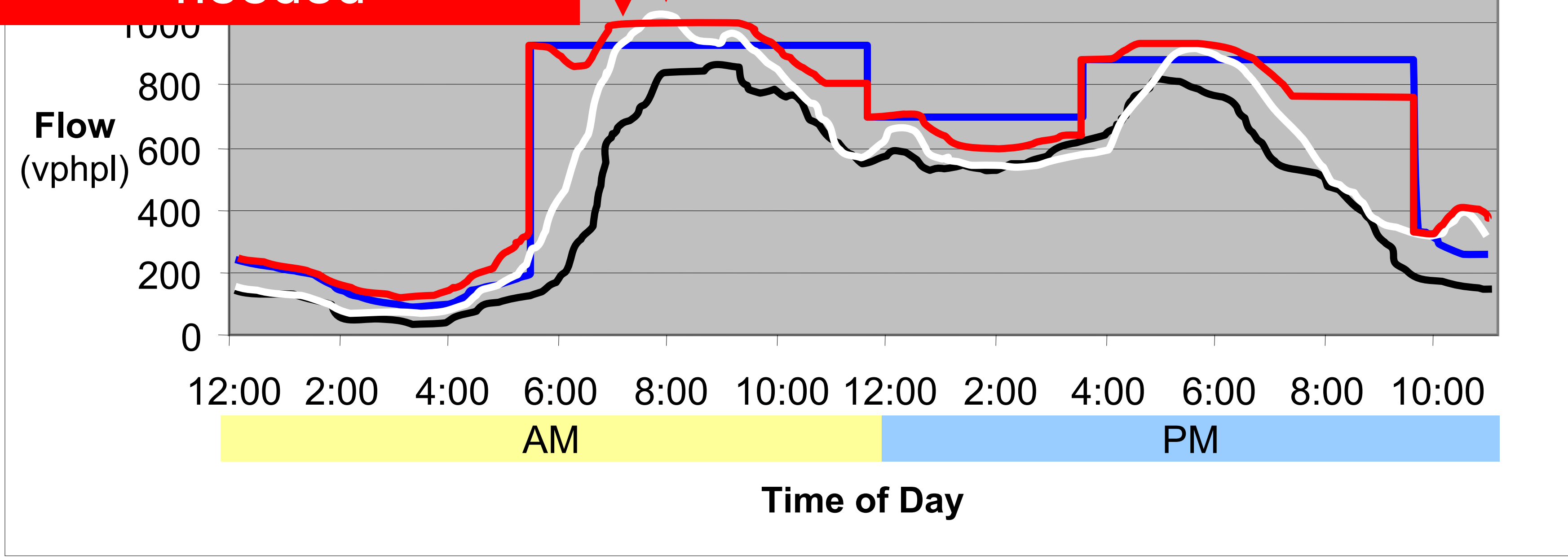


Illustration of Run-Time Refiner

Run-Time Refiner reallocates time where needed

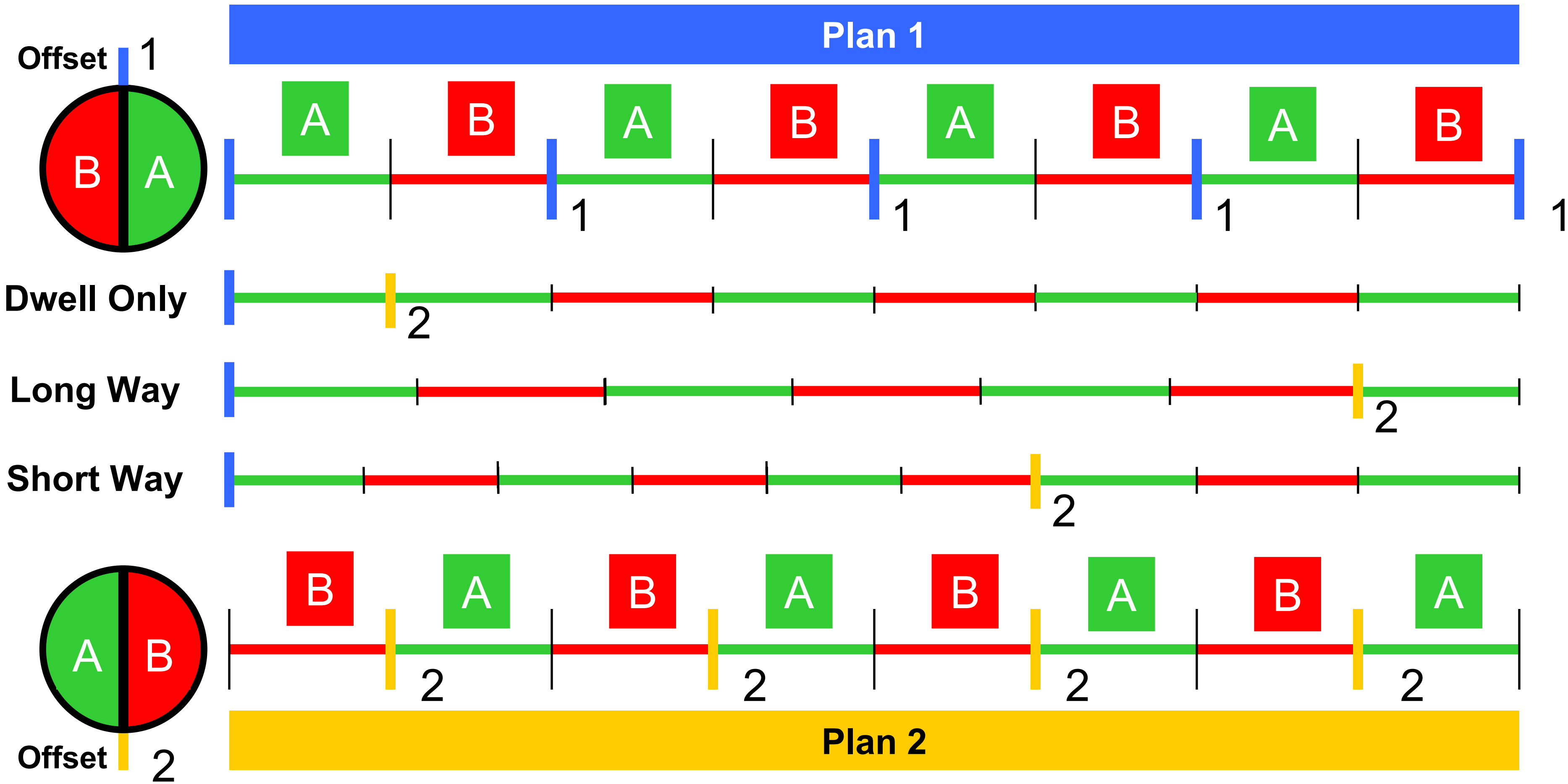
Better utilizes capacity of streets, but does not build new lanes



Transition Manager

- Manage controllers' transition from one plan to next
  - Select existing transition mode
    - Dwell
    - Add
    - Subtract
    - Best way (of Add/Subtract)
  - Command sequence of changes (TBD)
- Transition Objectives
  - Timely return to coordination
  - Minimally disruptive

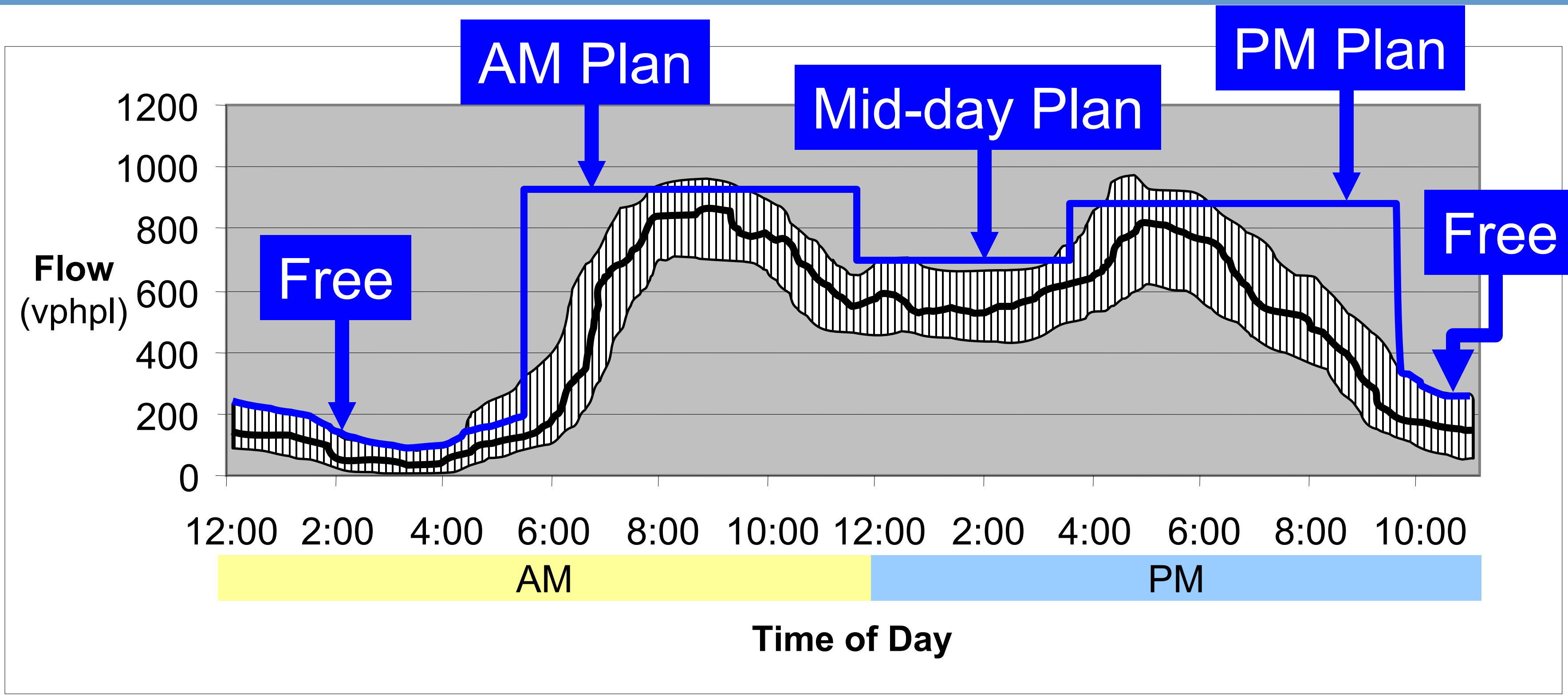
Illustration of Transition Manager



Time-of-Day Tuner

- Periodically re-tune Time-of-day (**TOD**) plans (TBD)
  - Adjust cycle, offset, & splits
  - Changes are “permanent”
  - Fine-tune schedule of pattern switch times
- Benefits
  - Avoid additional 3-5% delay/year due to changing traffic patterns
  - Remain effective during controller comm. failure
  - Plans tailored to accommodate daily variability
  - Respond to seasonal changes in traffic conditions

Illustration of Time-of-day Tuner



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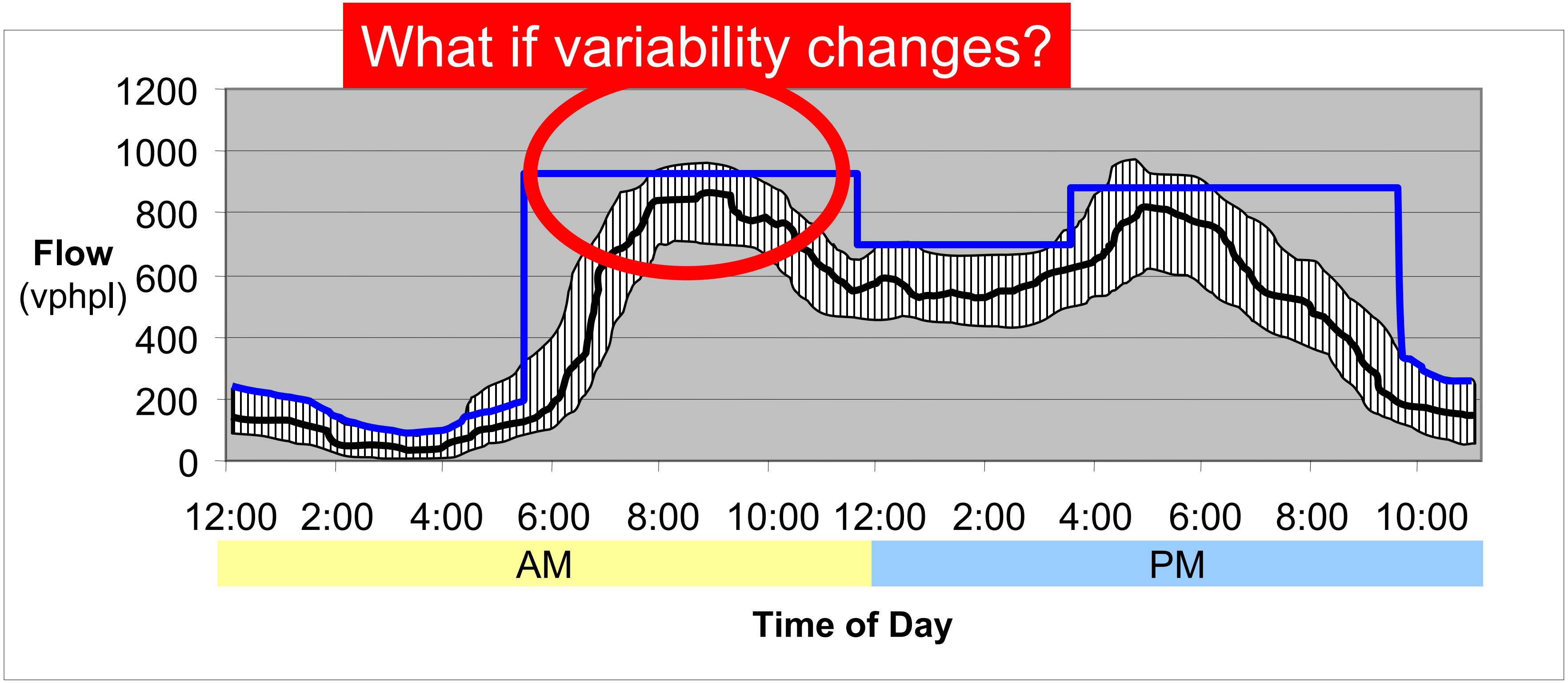

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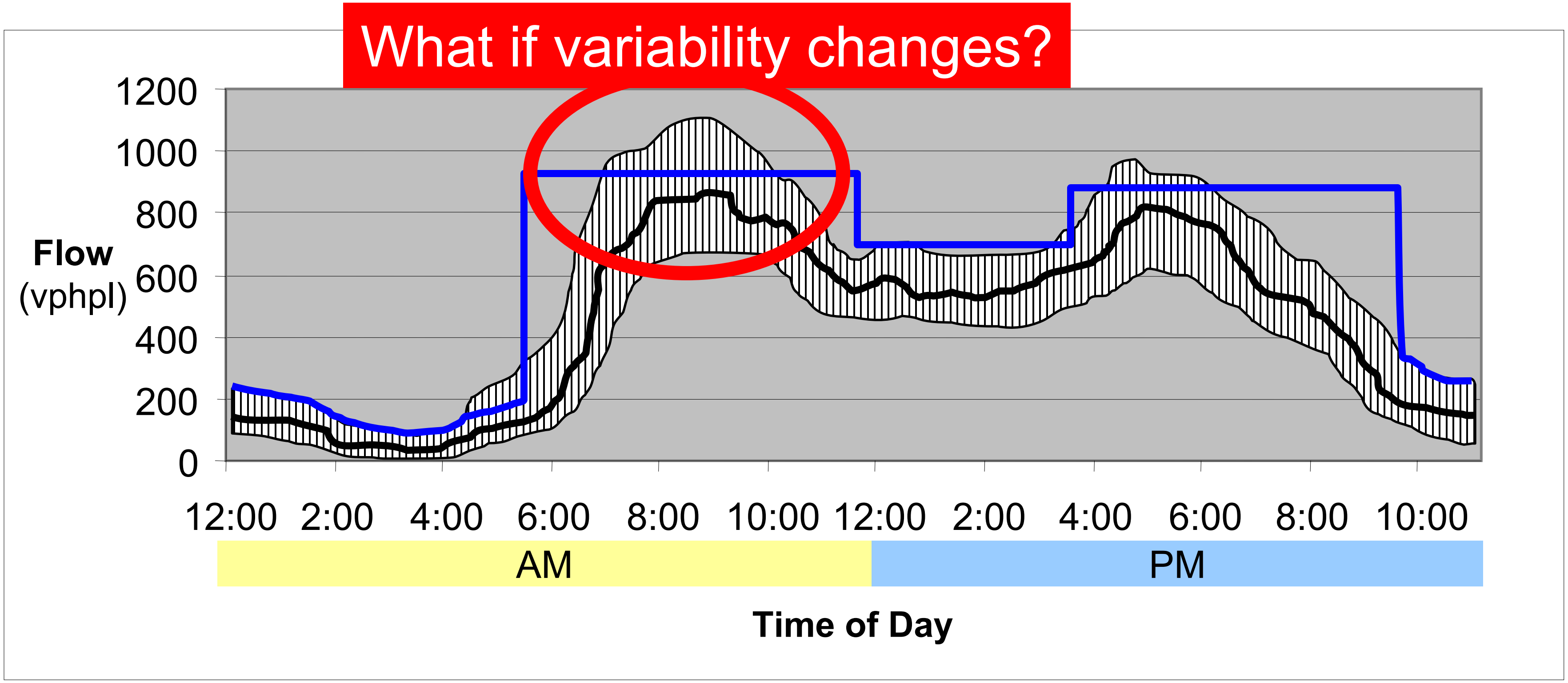
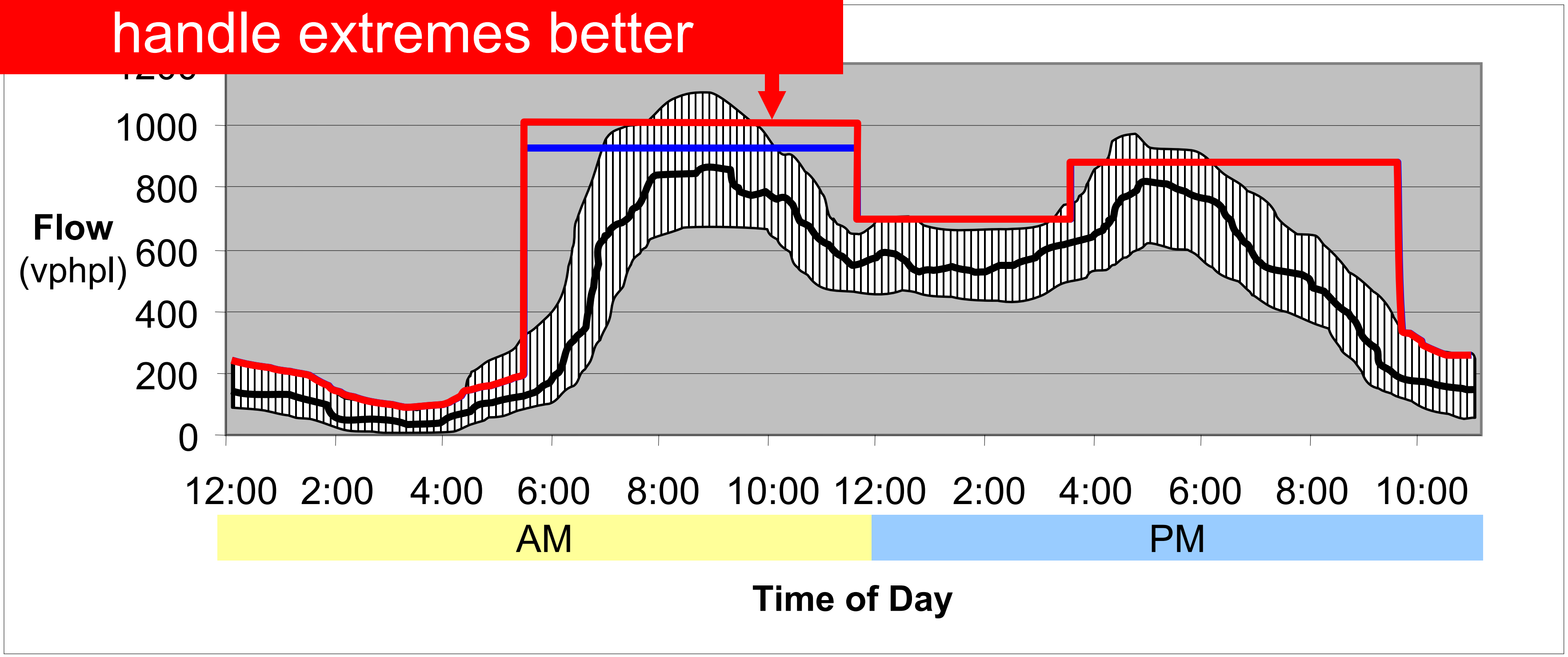


Illustration of Time-of-day Tuner

Time-of-Day Tuner adjusts to handle extremes better



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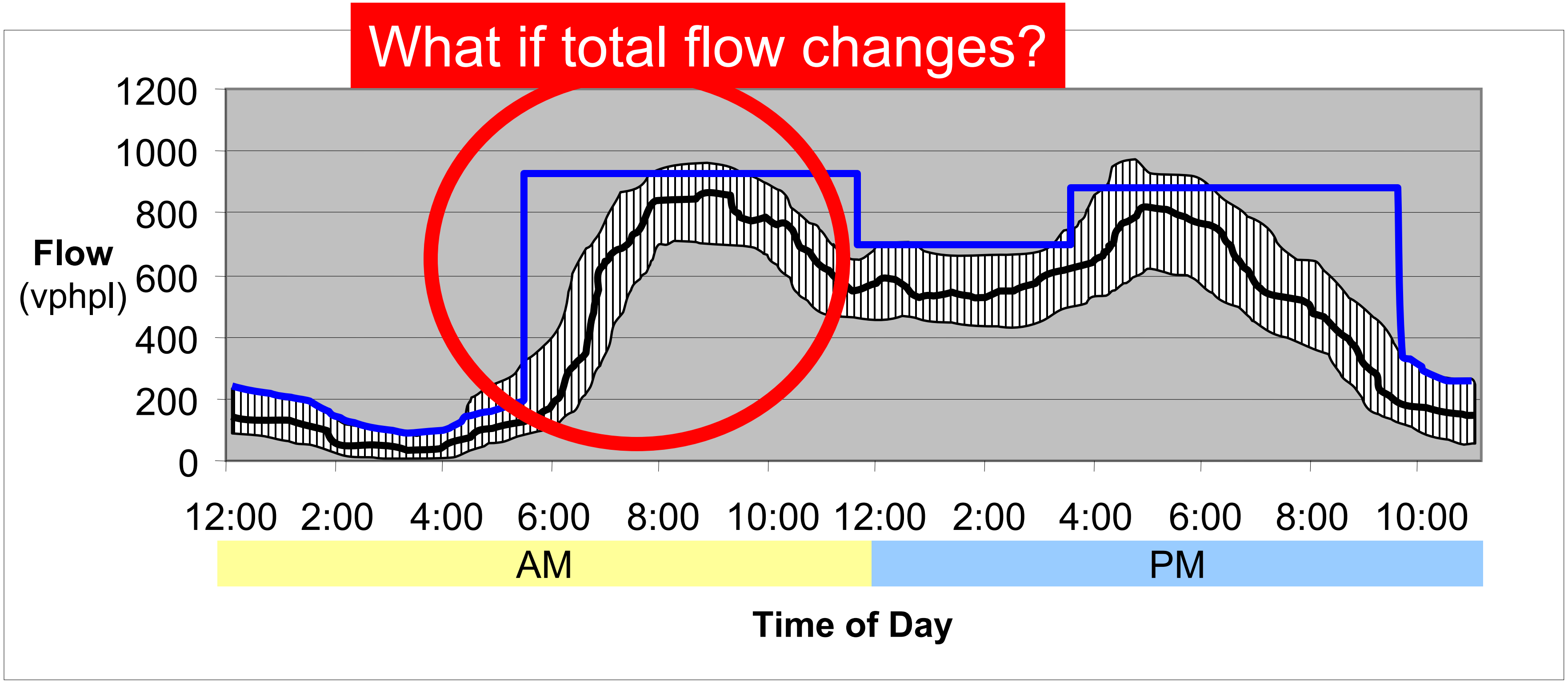

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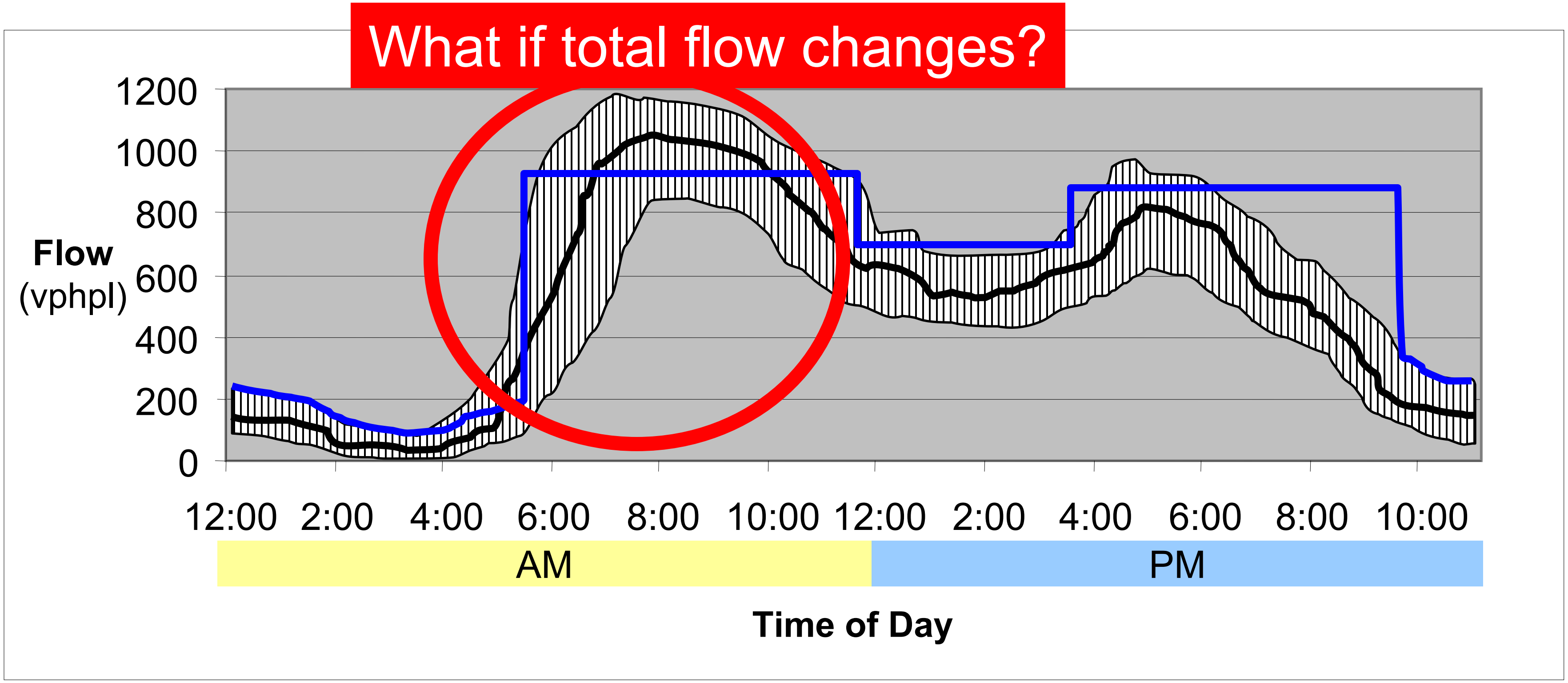

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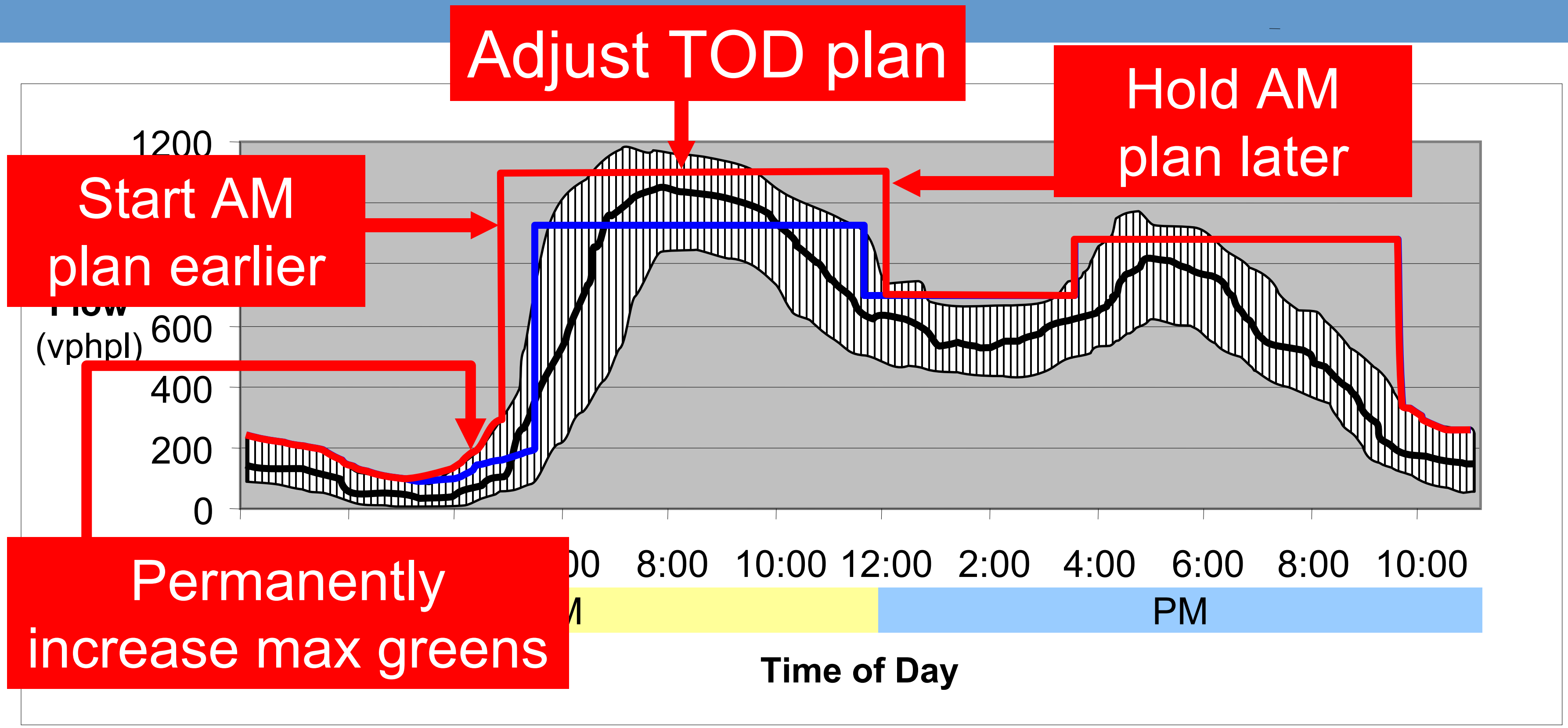
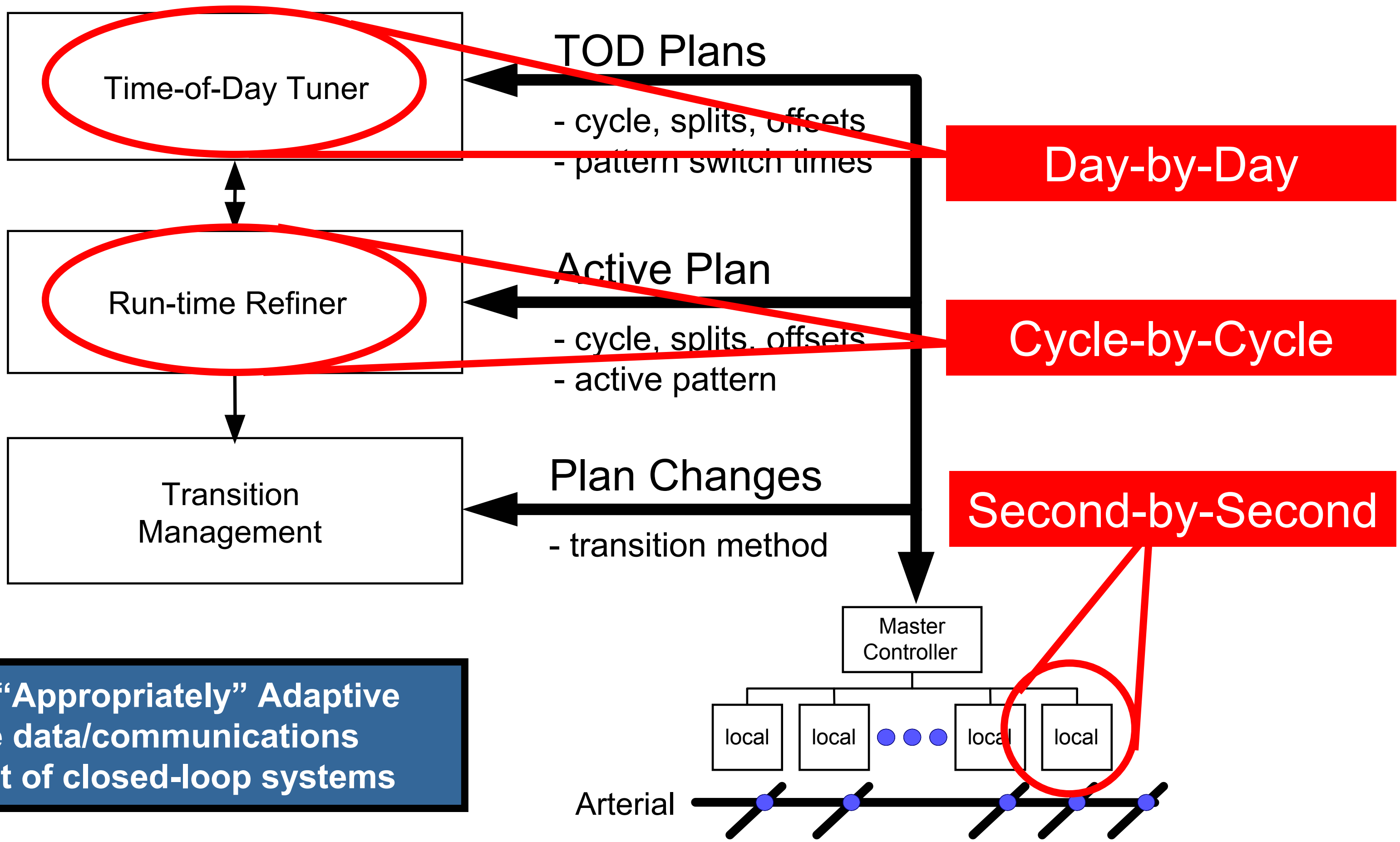


ACS-Lite Algorithms Architecture



ACS-Lite is "Appropriately" Adaptive within the data/communications environment of closed-loop systems

Run-Time Refiner Algorithm Details

- Splits
- Offsets

ACS Lite Split Adjustment Guidelines

- "EQUISAT" is most popular adaptive split strategy

1

- Volume & model parameters can be unreliable
- Use phase timing & termination data (not alone)
- Use lane independent green occupancy data

Capacity

2

- Account for early-return-to-green
- Reduce stops with intelligently biased splits
- Smart biasing requires arrival profile knowledge

Progression

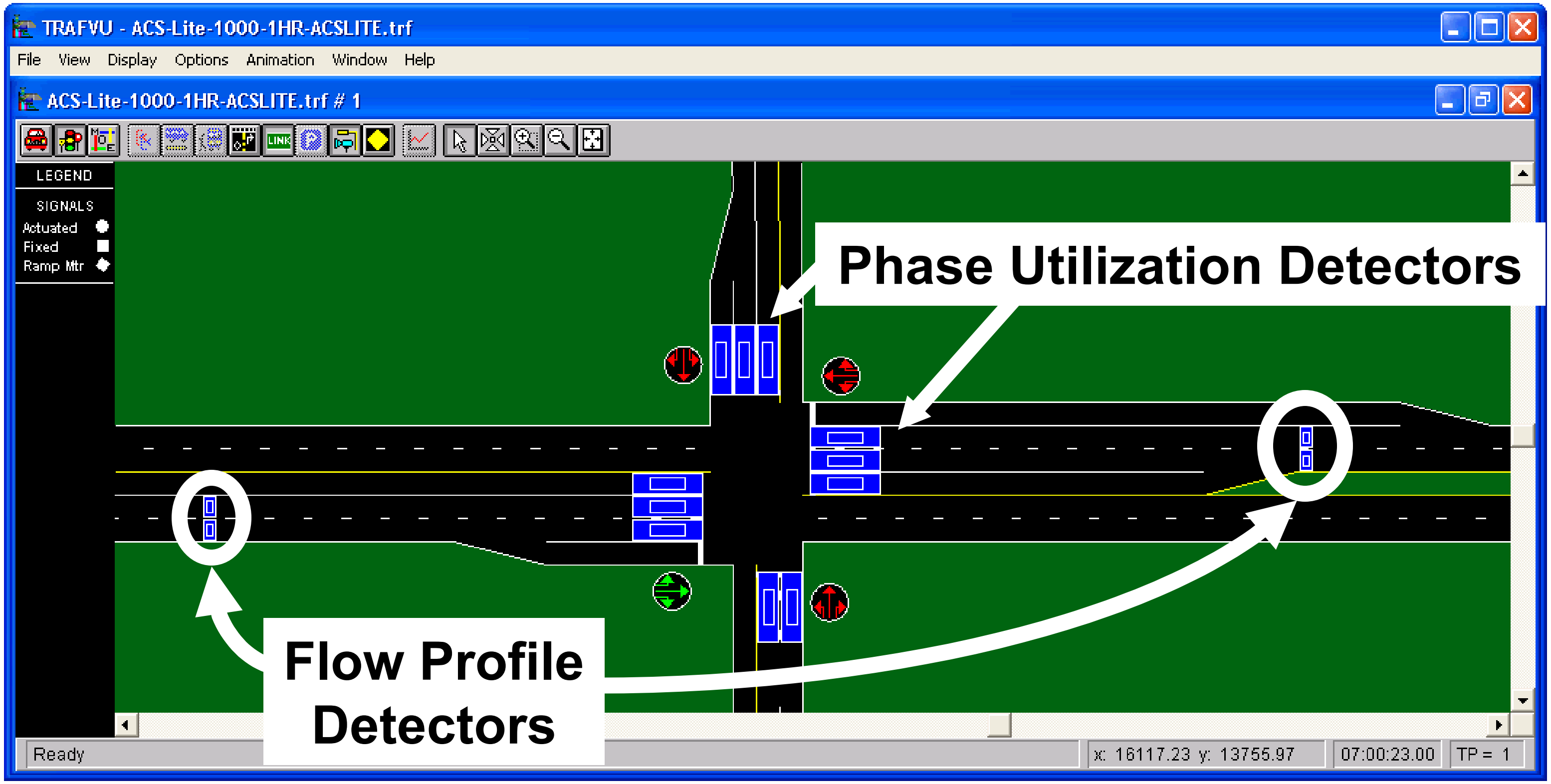
Split Adjustment Algorithm

Extend EQUISAT concept to **multi-ring** controllers

- STEP ONE: Form reasonable estimates of degree of saturation
- STEP TWO: Minimize the maximum level of saturation on any phase
  - Ensure barrier alignment & cycle time constraints are satisfied
  - Accommodate progression by allowing lower level of saturation on coordinated phases

Detector Layout

Need detectors at stop-bar of coordinated phases



Multi-ring Controller Terminology

- *Barrier group* (or just *group*)
  - The set of all phases (or ring-groups) between two barriers (or all phases if there are no barriers)
  - 2 groups below: {1,2,5,6} and {3,4,7,8}
- A *ring group* is the set of phases on a ring in a group
  - 4 ring-groups: {1,2}, {5,6},{3,4}, and {7,8}

b	1	2	a	3	4	b
	5	6		7	8	

Balance saturation within ring-group

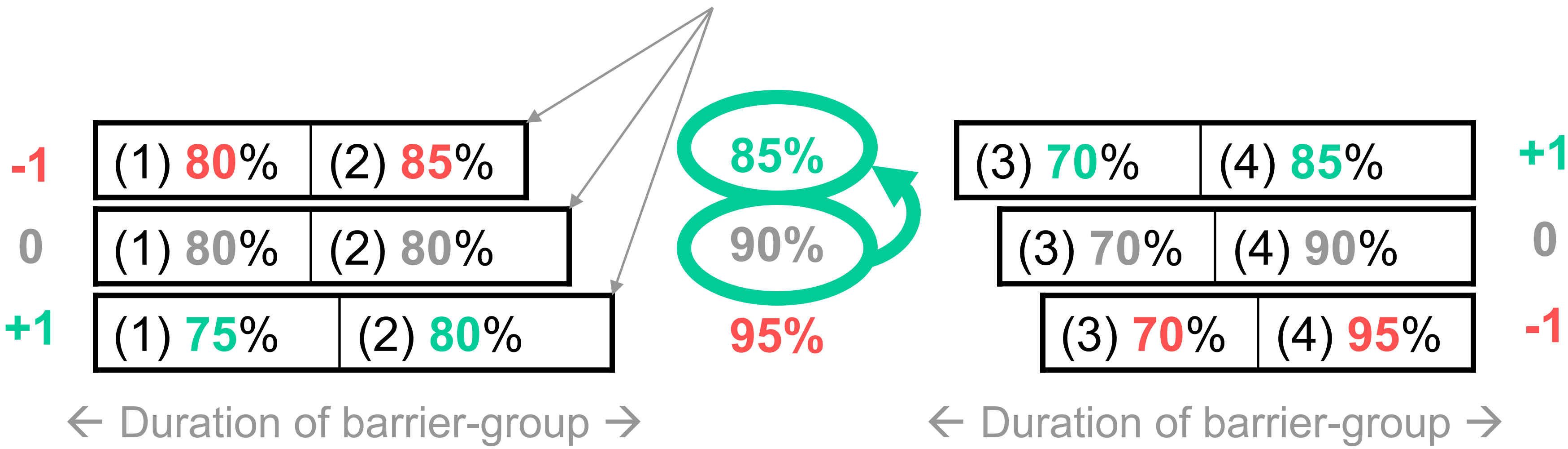
- Less split time => higher saturation
- More split time => lower saturation

	Degree of saturation estimates for each split allocation		MAX
Better splits for phases (1) & (2)	(1) 80%	(2) 80%	80%
Original splits for phases (1) & (2)	(1) 70%	(2) 85%	85%
Worse splits for phases (1) & (2)	(1) 65%	(2) 90%	90%

← Duration of ring-group →

Balance saturation across barrier groups

Degree of saturation estimates
for each barrier group duration



Accounting for all rings

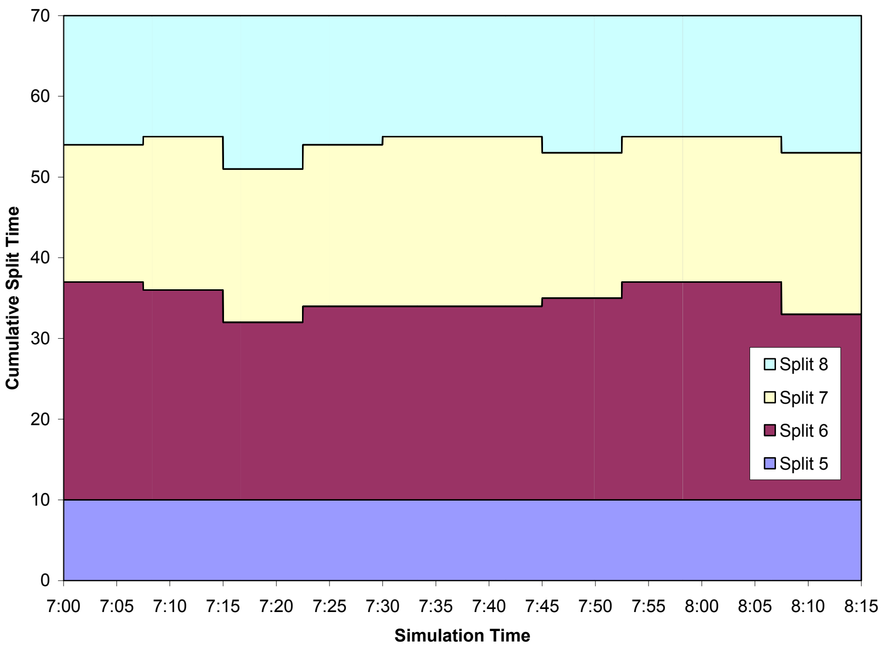
Degree of saturation estimates for each barrier group duration

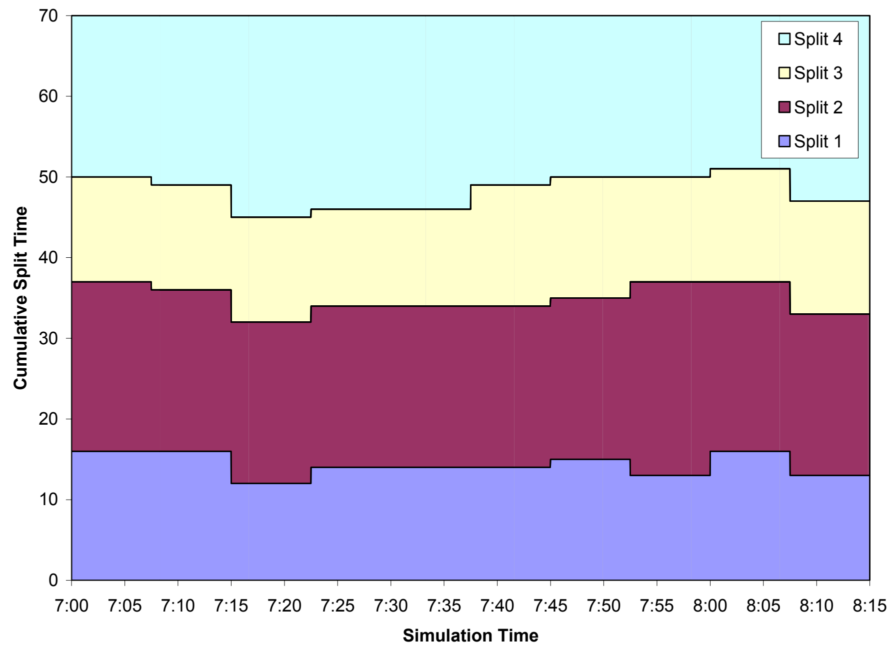
-1	(1) 80%	(2) 85%	85%	(3) 70%	(4) 85%	+1
0	(1) 80%	(2) 80%	90%	(3) 70%	(4) 90%	0
+1	(1) 75%	(2) 80%	95%	(3) 70%	(4) 95%	-1

← Duration of barrier-group → ← Duration of barrier-group →

-1	(5) 80%	(6) 87%	87%	(3) 60%	(4) 75%	+1
0	(5) 80%	(6) 83%	83%	(3) 60%	(4) 80%	0
+1	(5) 80%	(6) 80%	Inf.	Infeasible		-1

Typical split adjustment profile



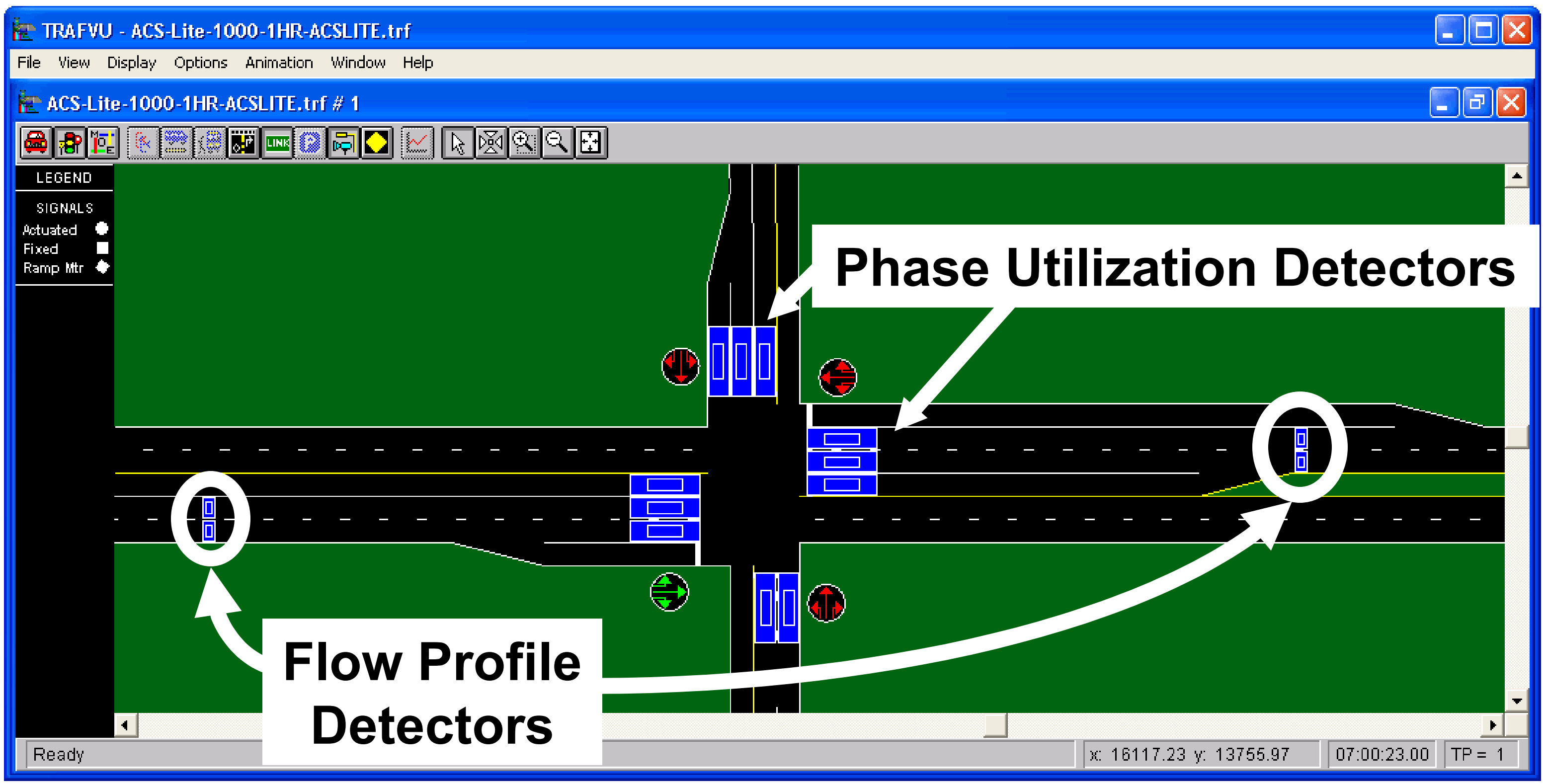


ACS Lite Offset Guidelines

- Measure cyclic flow profiles directly
- Account for travel time from the detector to the signal
- Account for variable start of green
- Account for both coordinated approaches and effect on downstream signals
- Maximize the total amount of captured flow
  - Two options:
    - On inbound and outbound movements at ALL signals on the arterial
    - On inbound and outbound movements at EACH signal on the arterial independently
- Make small incremental changes to minimize transitions

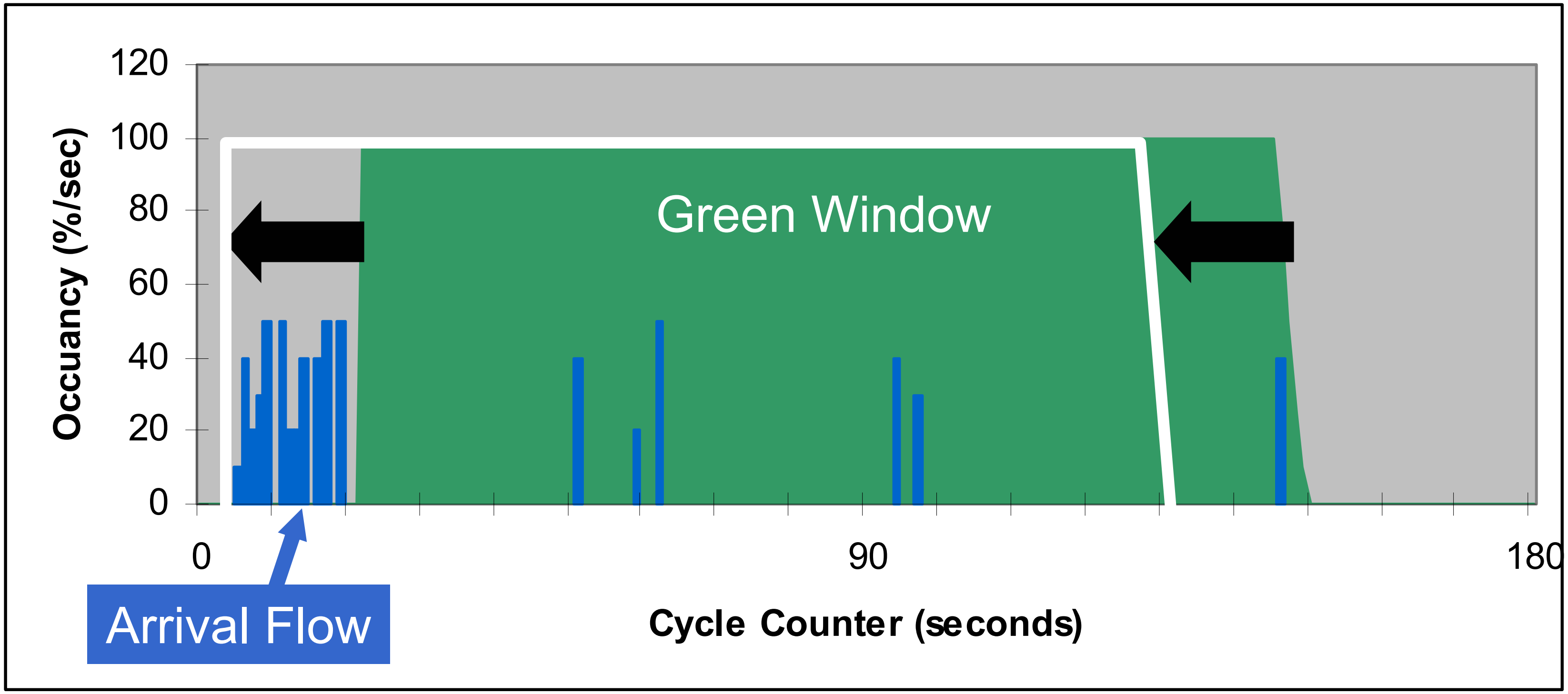
Detector Layout

Need detectors at stop-bar of coordinated phases



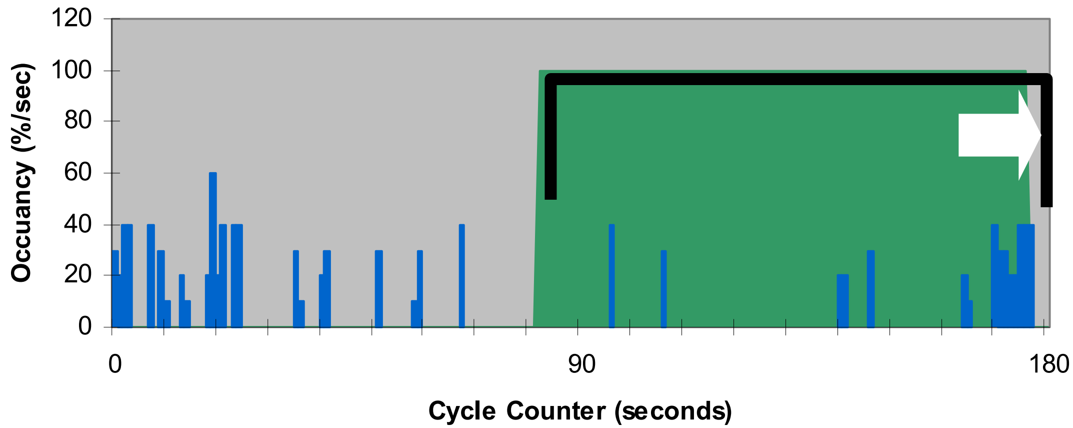
Local Offset Tuning

Shift to capture most arriving flow

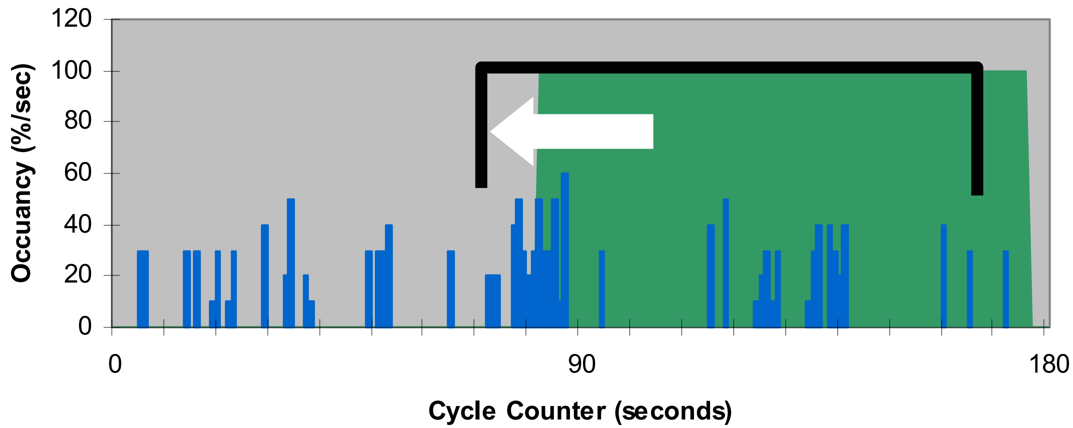


Account for all coordinated approaches

Southbound

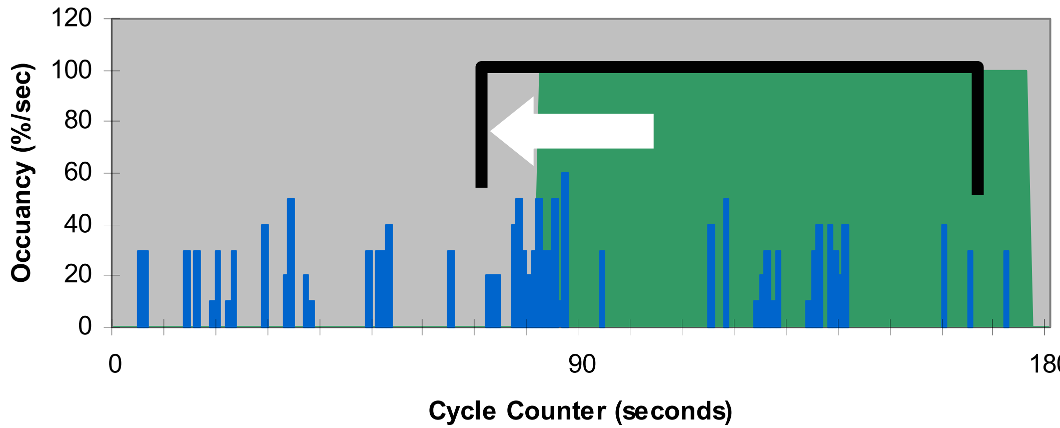


Northbound



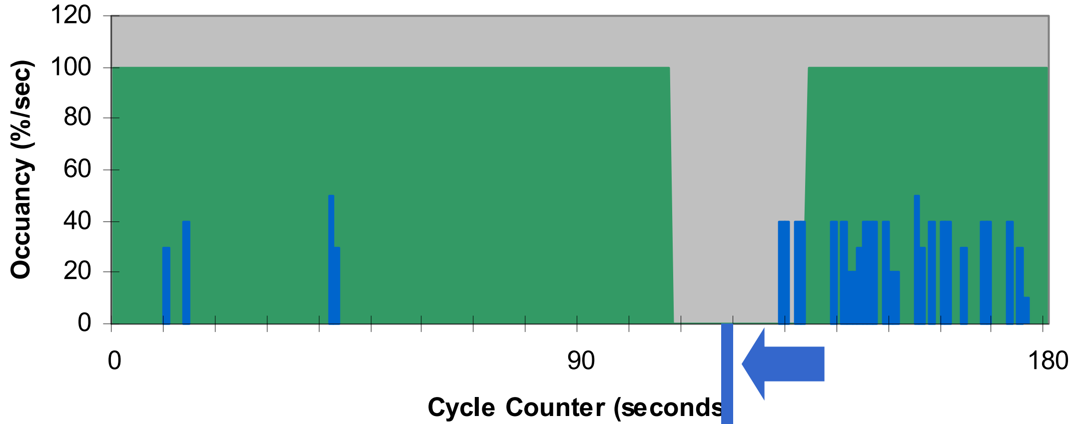
Account for all downstream signals

Upstream



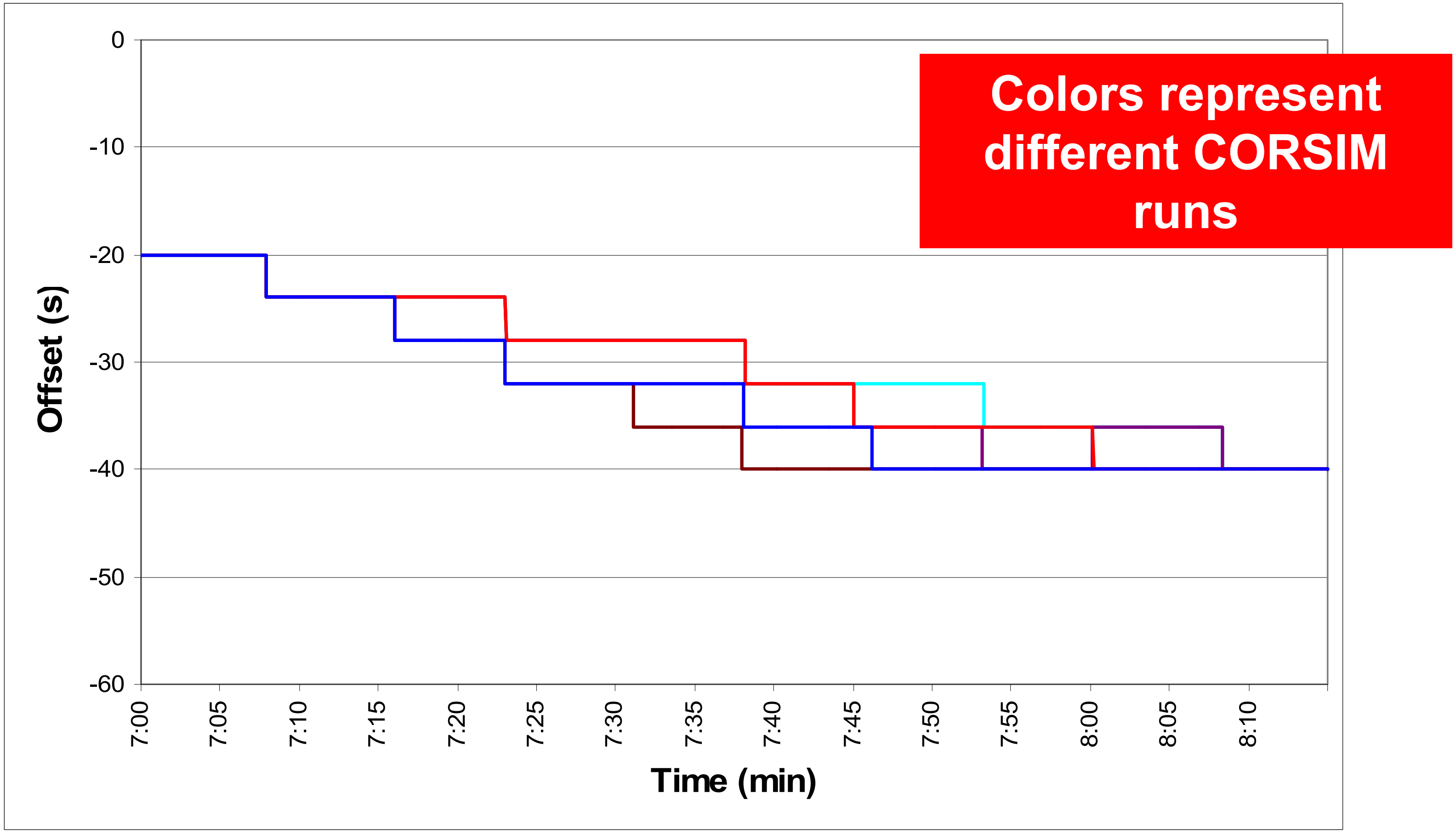
Shifting earlier reduces stops locally

Downstream



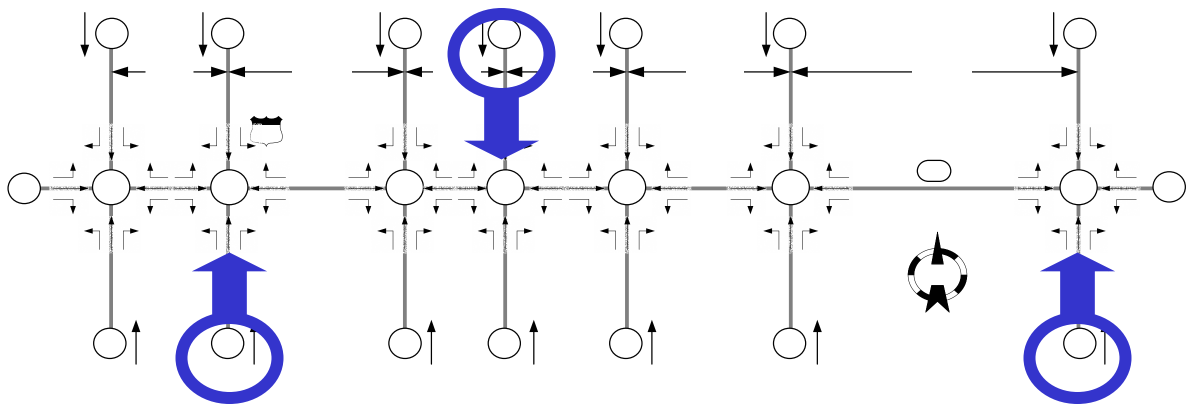
Upstream shift would increase stops

Typical offset adjustment profile



Simulation Performance Testing

- ITT Industries
  - Developed NTCIP agent interface to CORSIM
  - Developed multi-pattern capability and realistic transition logic
- Purdue
  - Developed “real-world” test scenarios
  - Synchro-optimized timings
  - Many, many, many simulation runs and independent assessment of results

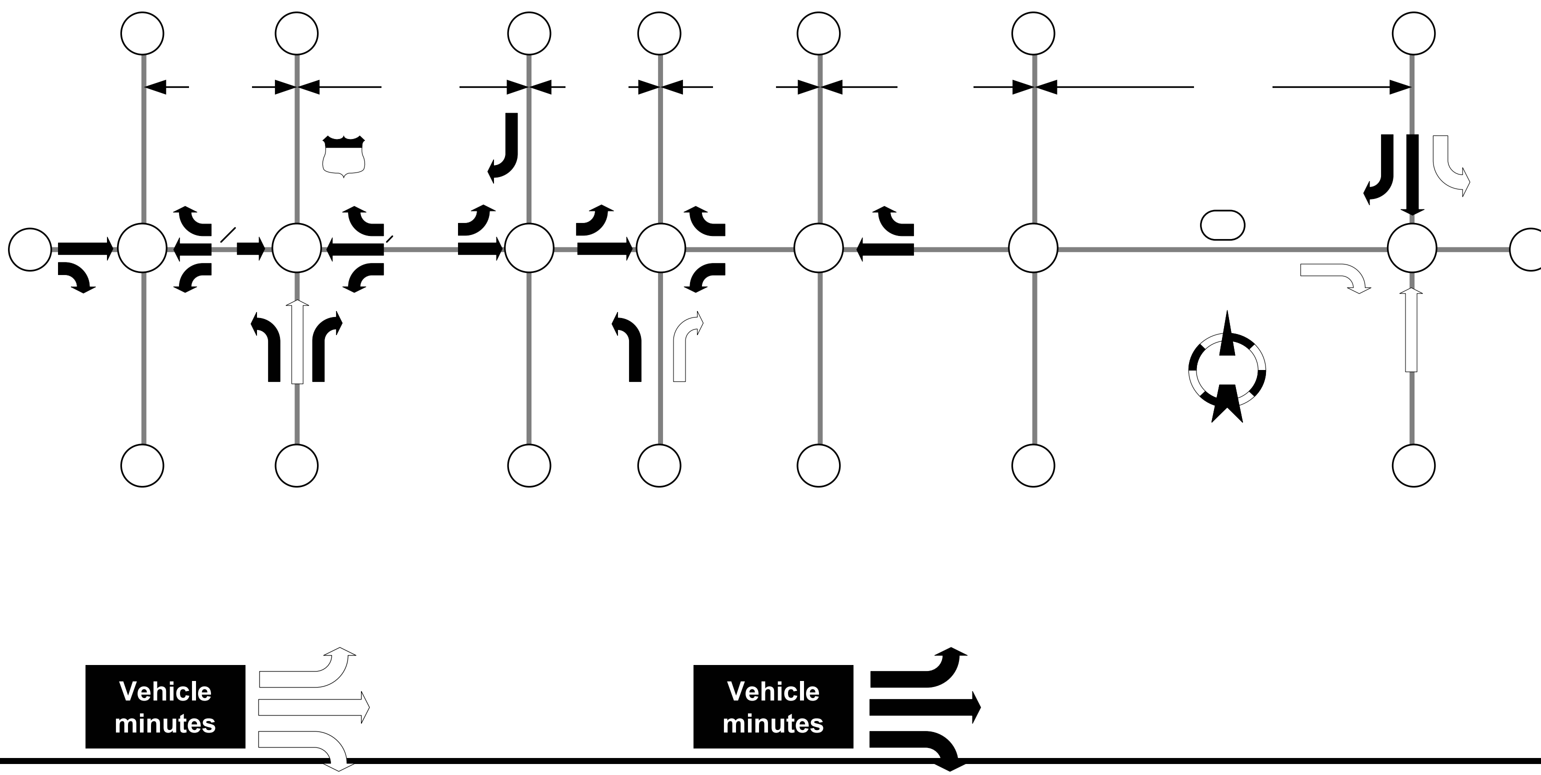


Simulation Performance Testing

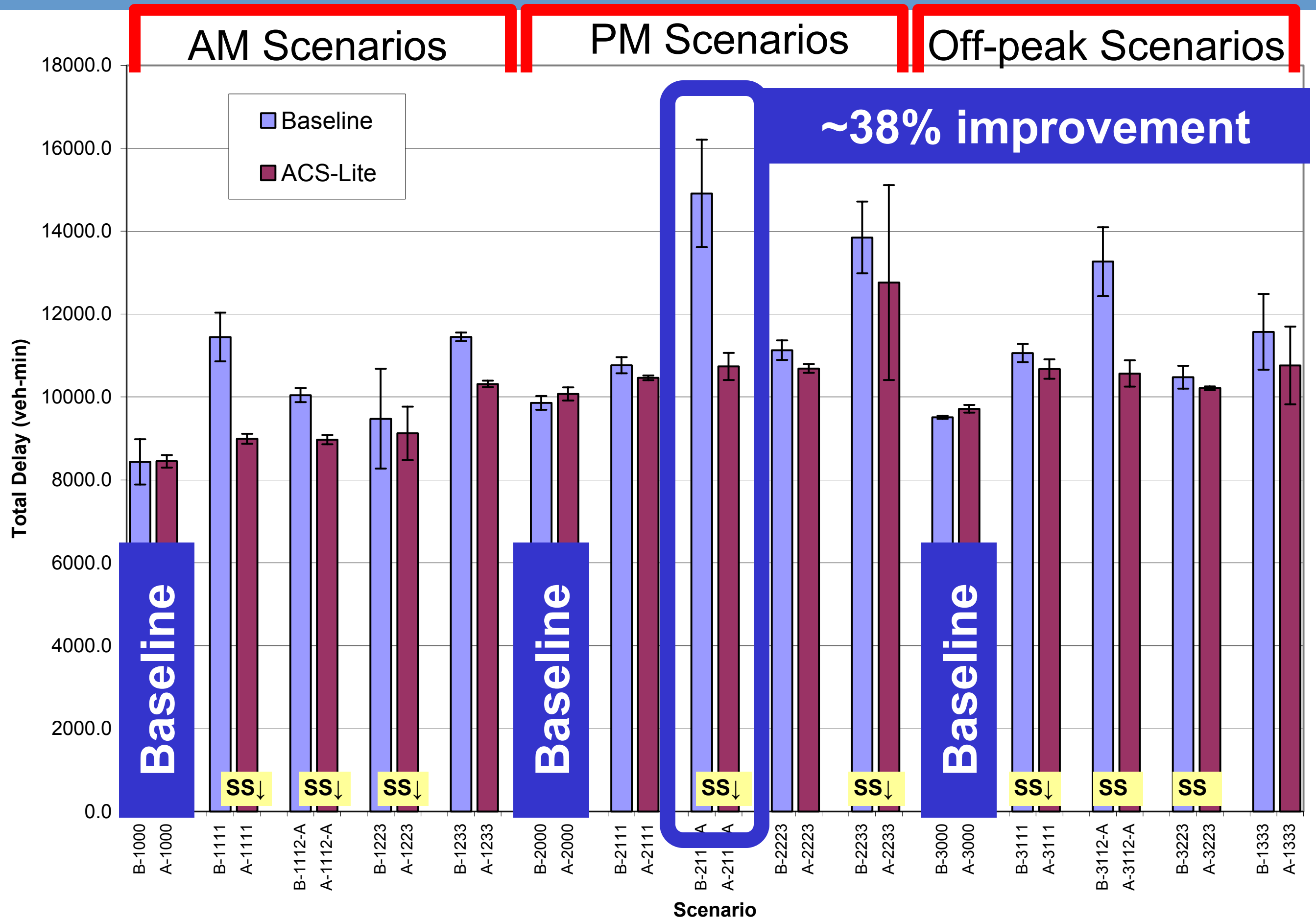
- Evaluate algorithms parameters
  - Re-adjustment intervals (5 to 10 minutes)
  - Offset changes and max deviations (2 to 20 seconds, “any”)
  - Split adjustments and max deviations (2 to 20 seconds, “any”)
  - Results tend towards shorter re-adjustment intervals and larger flexibility of algorithm to make adjustments
- Start with optimized timings – can ACS-Lite improve?
- Start with bad/arbitrary offsets or splits – can ACS-Lite find a good solution?
- Change turning proportions and volumes to represent real-world traffic changes – can ACS-Lite adapt?

Simulation Performance Testing

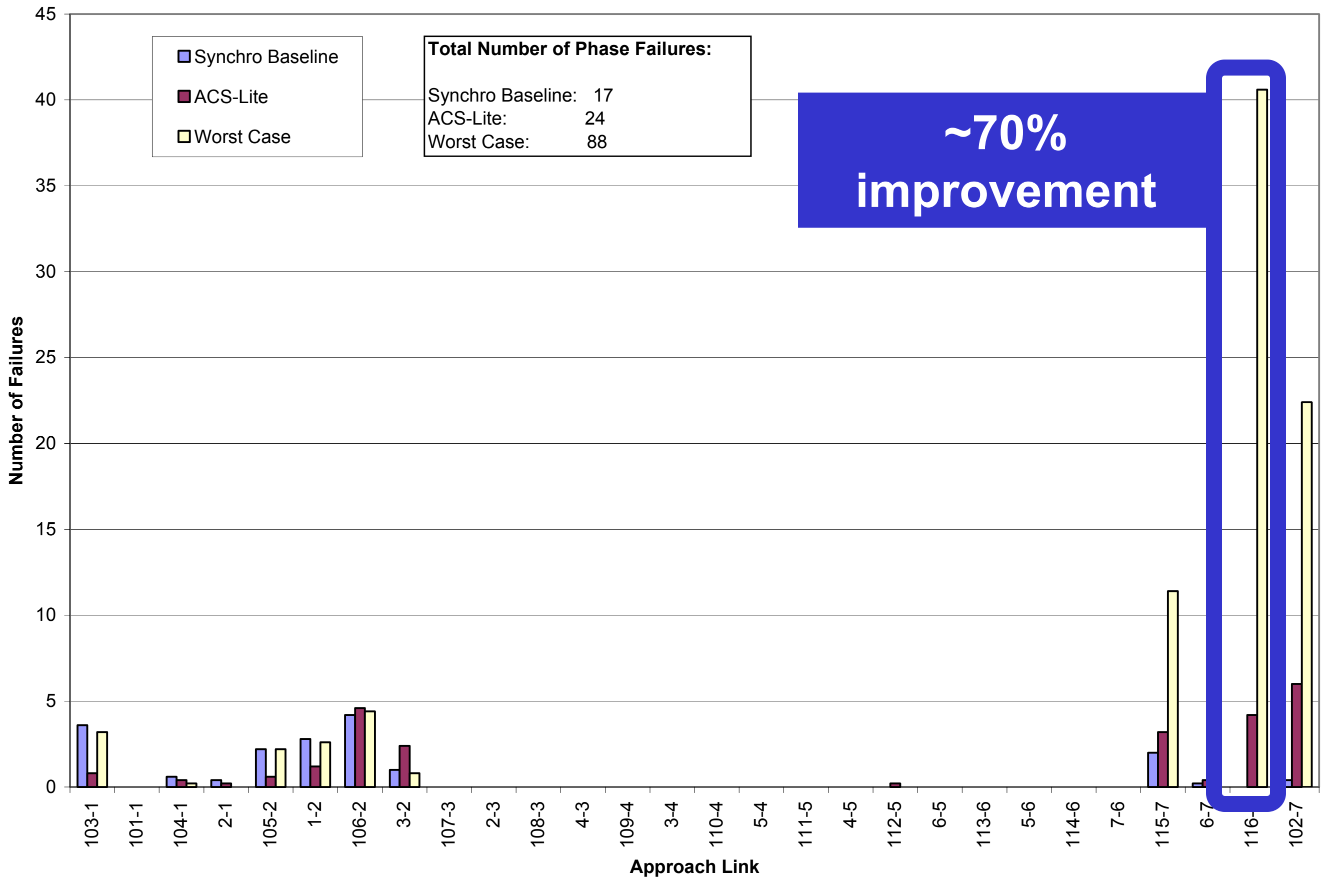
Changes in volumes at side-street approaches to intersections 2, 4, and 7 impact the entire network



Evaluation Results – Total Control Delay



Evaluation Results – Phase Failures



"Very High Altitude" Evaluation Results

ACS-Lite test scenario	vs. "Do nothing", initially as ACS-Lite	Conclusion
Start with optimized settings	Delay (-0.0%, +0.7%) Travel Time (-0.6%,+2.4%)	ACS-Lite "does no harm"
Start with bad Offsets (no split adjustment)	Delay (-**4.2%**, +0.9%) Travel Time (-**4.0%**,+1.3%)	ACS-Lite can find a good set of offsets
Start with bad side-street Splits (no offset adjustments and progression bias)	Delay (-**3.3%**, +**2.2%**) Travel Time (-**4.9%**,+**6.8%**)	ACS-Lite usually makes improvement
Changing volumes & turning proportions	Delay **(-38%, -7.4%)** Travel Time **(-6.4%, +3.5%)**	ACS-Lite provides consistent delay reduction

Conclusions

- Core ACS-Lite development is complete
  - Run-Time Refiner
  - Transition Manager
  - Communications and algorithms software infrastructure
- Performance evaluation in simulation is encouraging
- Current configuration designed for up to 12 intersections on arterial
- Coming up
  - TReL testing with Hardware-in-Loop
  - Field testing
  - Time-of-day Tuner algorithms development

Questions?

Hunt us down for a demo