Signal Optimization and Analysis Using PASSER V-07

Training Workshop: Code IPR006

Nadeem Chaudhary (n-chaudhary@tamu.edu)
Chi-Leung Chu (clchu@tamu.edu)
Steve Venglar (s-venglar@tamu.edu)

TxDOT Implementation Project 5-5424-01
Product 5-5424-01-P1

Session 0: Preliminaries

- Self Introductions
- Workshop Objectives
- Workshop Outline

S0–Workshop Objectives

- **Learn Use of PASSER V for Analysis and Optimization of Traffic Signals:**
  - ✓**Isolated TWSC Intersections**
  - ✓**Isolated Signals**
  - ✓**Arterials and Sub-arterials**
  - ✓**Isolated Diamond Interchanges**
  - ✓**Diamonds + Adjacent Signals**

S0–Workshop Outline

- S1: Introduction to PASSER V
  - ✓Features
  - ✓Basic Operations
- S2: Isolated TWSC Intersections
  - ✓Review of Theory
  - ✓Exercise
- S3: Isolated Signals
  - ✓Review of Theory
  - ✓Exercise

S0–Workshop Outline *(continued)*

- **S4: Signal Systems**
  - ✓**Review of Theory**
- **S5: Arterial Analysis**
  - ✓**Analyze Simple Arterials**
  - ✓**Review Additional Features**
- **S6: Diamond Interchange Analysis**
  - ✓**Additional Discussion**
  - ✓**Exercise**

S0–Workshop Outline *(continued)*

- **S7: Diamond and Adjacent Signals**
  - ✓ **Coordinating Diamond with Adjacent Signals**
- **S8: Workshop Conclusion**
  - ✓ **Question/Answer Session**
  - ✓ **Workshop Survey**

Session 1: Introduction to PASSER V

- Background
- Features
- Input Data Requirements
- User Interface

S1–PASSER V Background

- Funded by TxDOT and TTI
- Applications
  - ✓Isolated Signals (Building Blocks)
  - ✓Isolated TWSC Intersections
  - ✓Signalized Arterials
  - ✓Isolated Diamond Interchanges
  - ✓Diamond + Adjacent Signals

S1–PASSER V Features

- Graphic User Interface
  - ✓Multiple Document Architecture
- Mesoscopic Delay/Traffic Model
- Can Coordinate Signals to Provide
  - ✓Maximum Progression
  - ✓Minimum Delay
- Graphic Time-Space Diagram

S1–Using PASSER V

- Draw the Facility
- Select Intersection or Link
- Enter Corresponding Data
- View Signal MOEs
- Analyze/Optimize Signal Systems
  - ✓Select and Run Tool
  - ✓View/Print Results

S1–Tools in PASSER V

- PASSER II Optimizer
- PASSER III Optimizer
- GA-Based Optimizer
- Time-Space Diagram Generator
- Volume Analysis
- Delay Analysis

S1–PASSER V Limitations

- **Coordination Requires Same Cycle Length at All Signals**
  - ✓ **No Double-Cycling or Conditional Service**
- **Cannot Handle Following Cases**
  - ✓ **One-Step Network Optimization**
  - ✓ **All-way Stop-controlled Intersections**

Session 2: Isolated TWSC Intersections

- Input Data Needs
- Overview of Theory
- Isolated Intersection Exercise

S2–PASSER V Data Needs

- **Turning Movement Counts (TMC)**
  - ✓ **Collect 15-Minute Data and Calculate PHF**
  - ✓ **AM, PM, and Off-Peak**
  - ✓ **Collect Vehicle Mix Information**
- **Intersection Configurations**
  - ✓ **Number of Lanes, Lane Use, Lane Widths, Turn Bays and Lengths, Median Type, etc.**
- **Can Apply Growth Rates to Older Counts as Long as Traffic Patterns Haven't Changed**

S2–Exercise

Node Data

Controller Id: 3

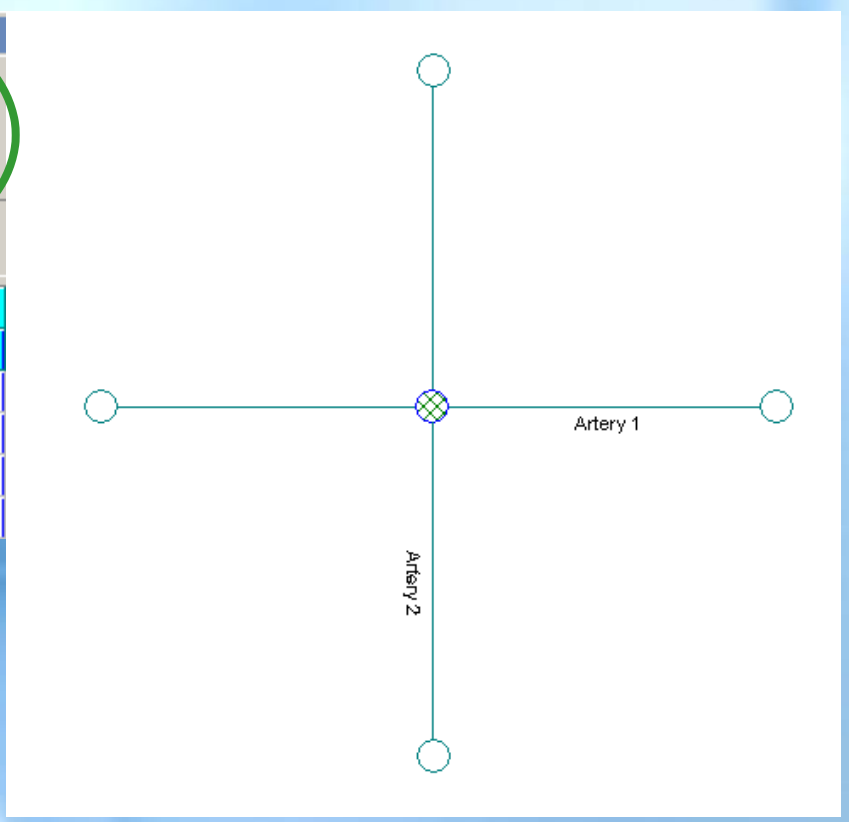
Area Type: Other

Intersections: Artery 1 at Artery 2

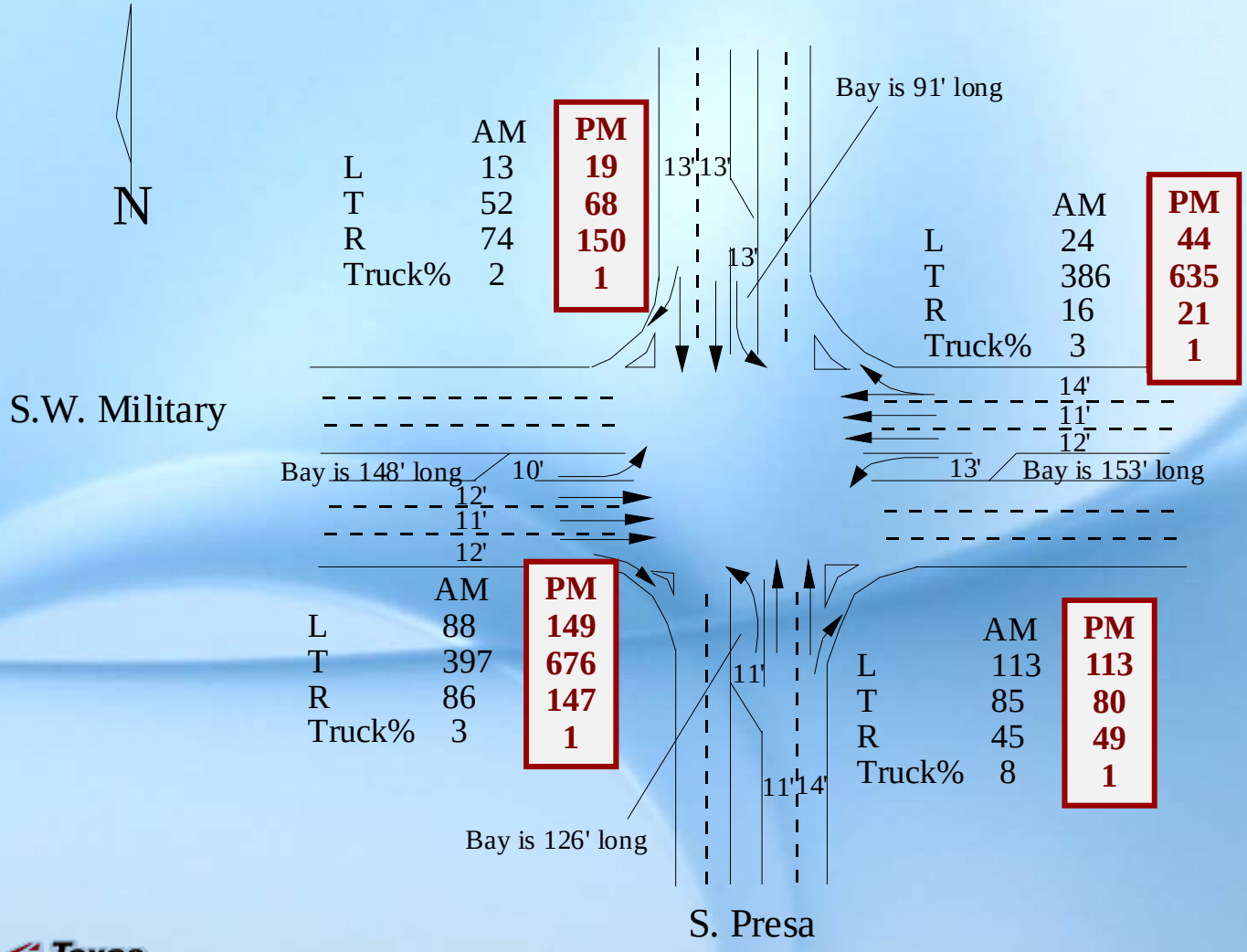
Controller Type: Unsignalized-TWSC

Intersection Data | Capacity Data | Headway Data | MOEs

Artery	Artery 1					
Movement	EBL	EBT	EBR	WBL	WBT	WBR
Lane Assignment	1	3 >	< 1	1	3 >	< 1
Volume (vph)	149	676	147	44	635	21
Sign	Free	Free	Free	Free	Free	Free
Channelized Right Turn			Yes			Yes

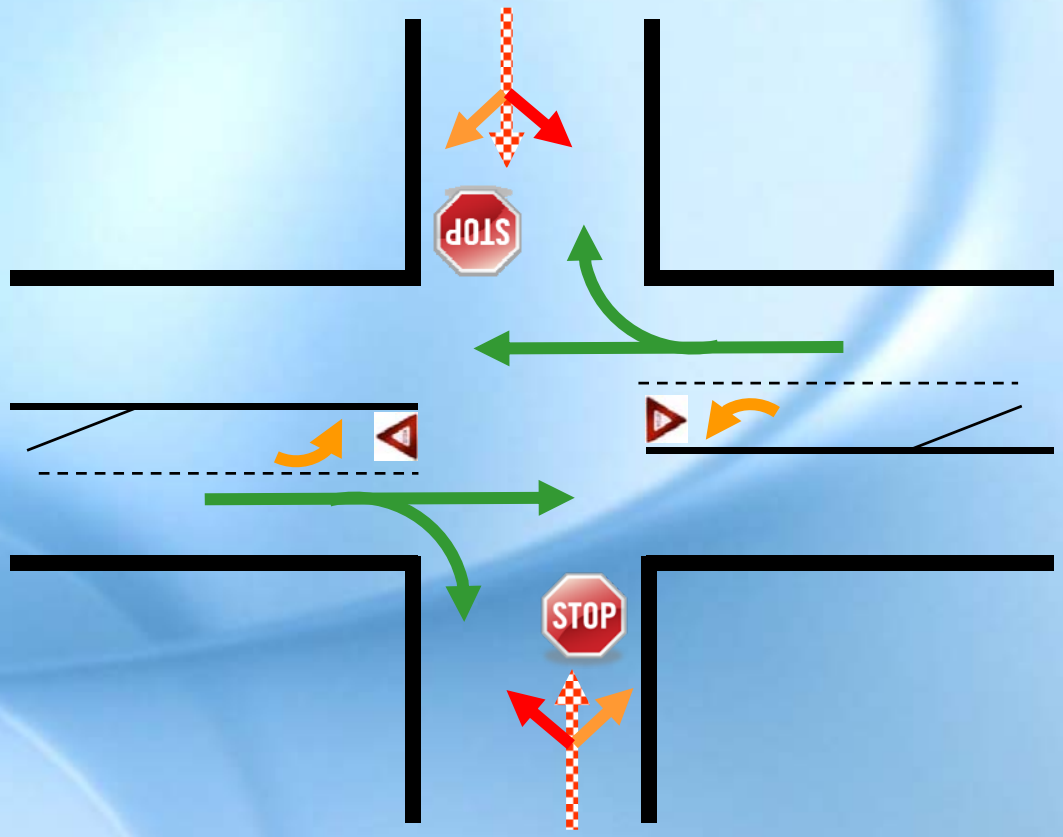


S2–Exercise (User Guide, p. 91)

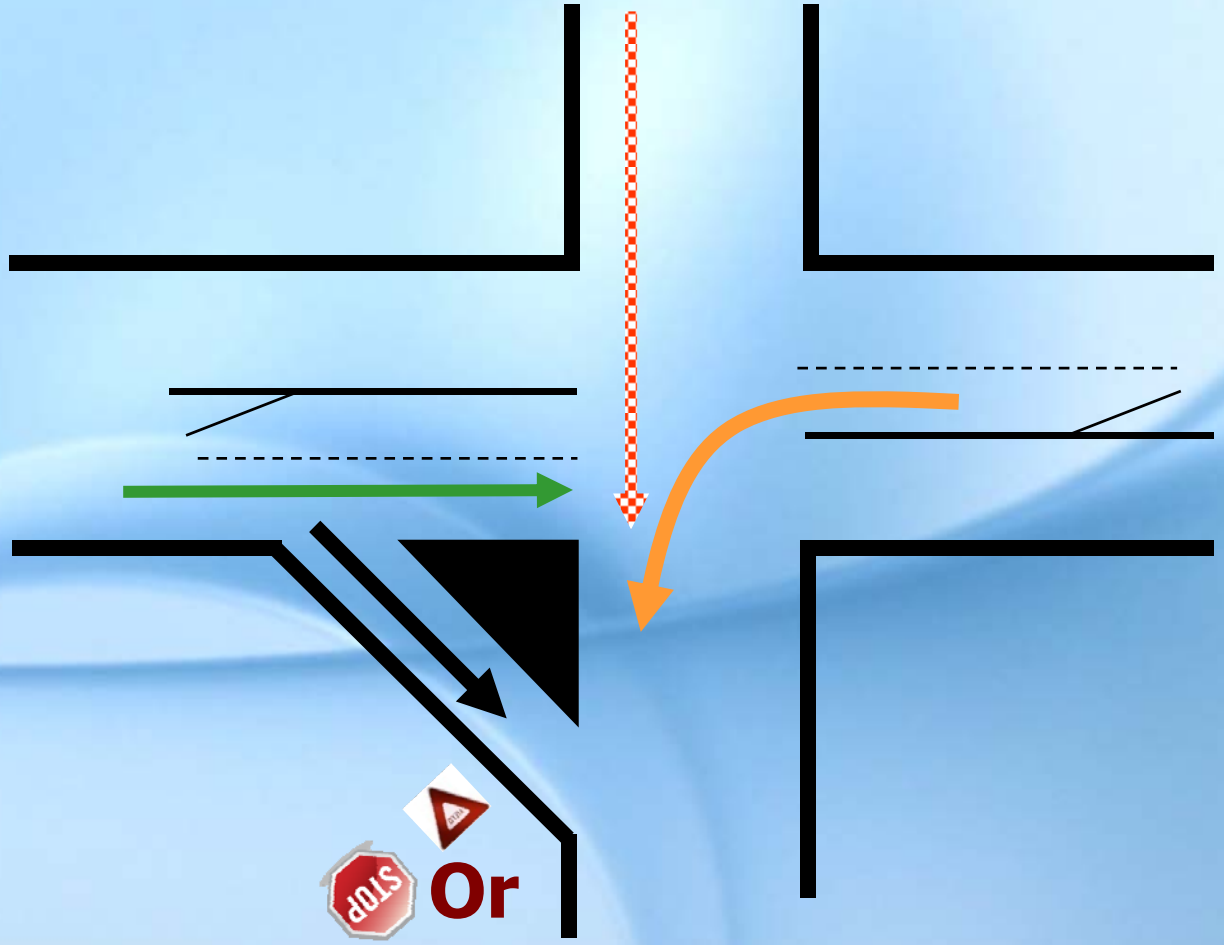


S2–Gap Acceptance

- Movement Ranks
- Process
  - ✓Observe Headways
  - ✓Accept Gap

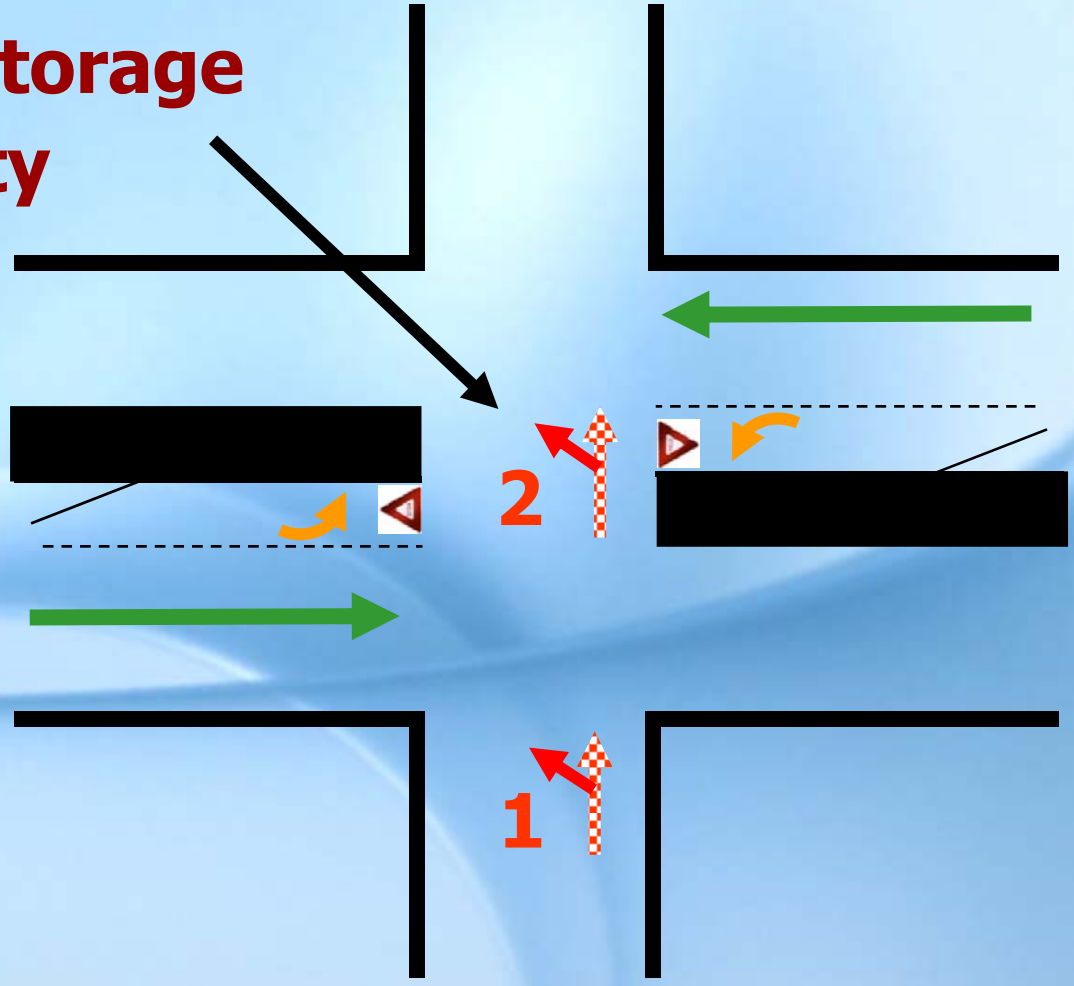


S2–Channelized Rights



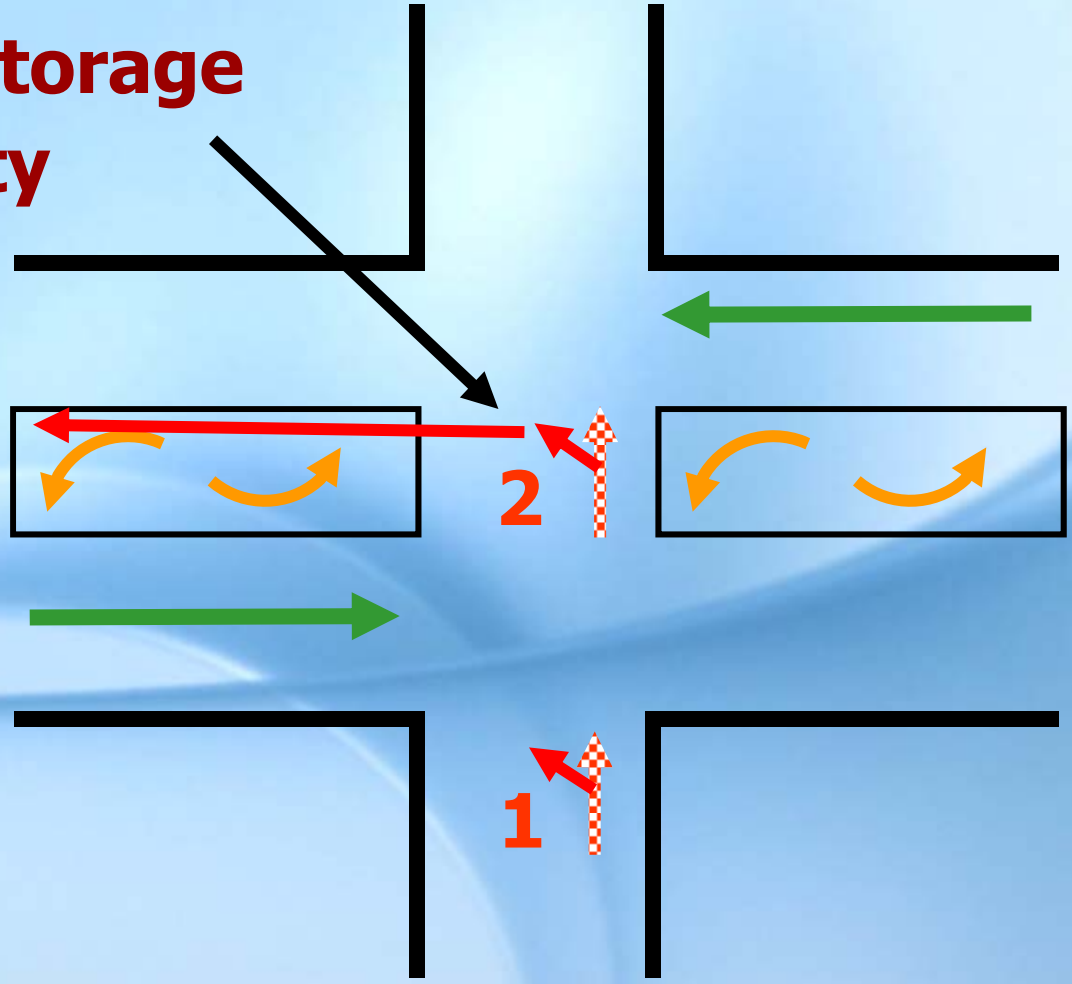
S2–Two-Stage Process

Enter Storage Capacity

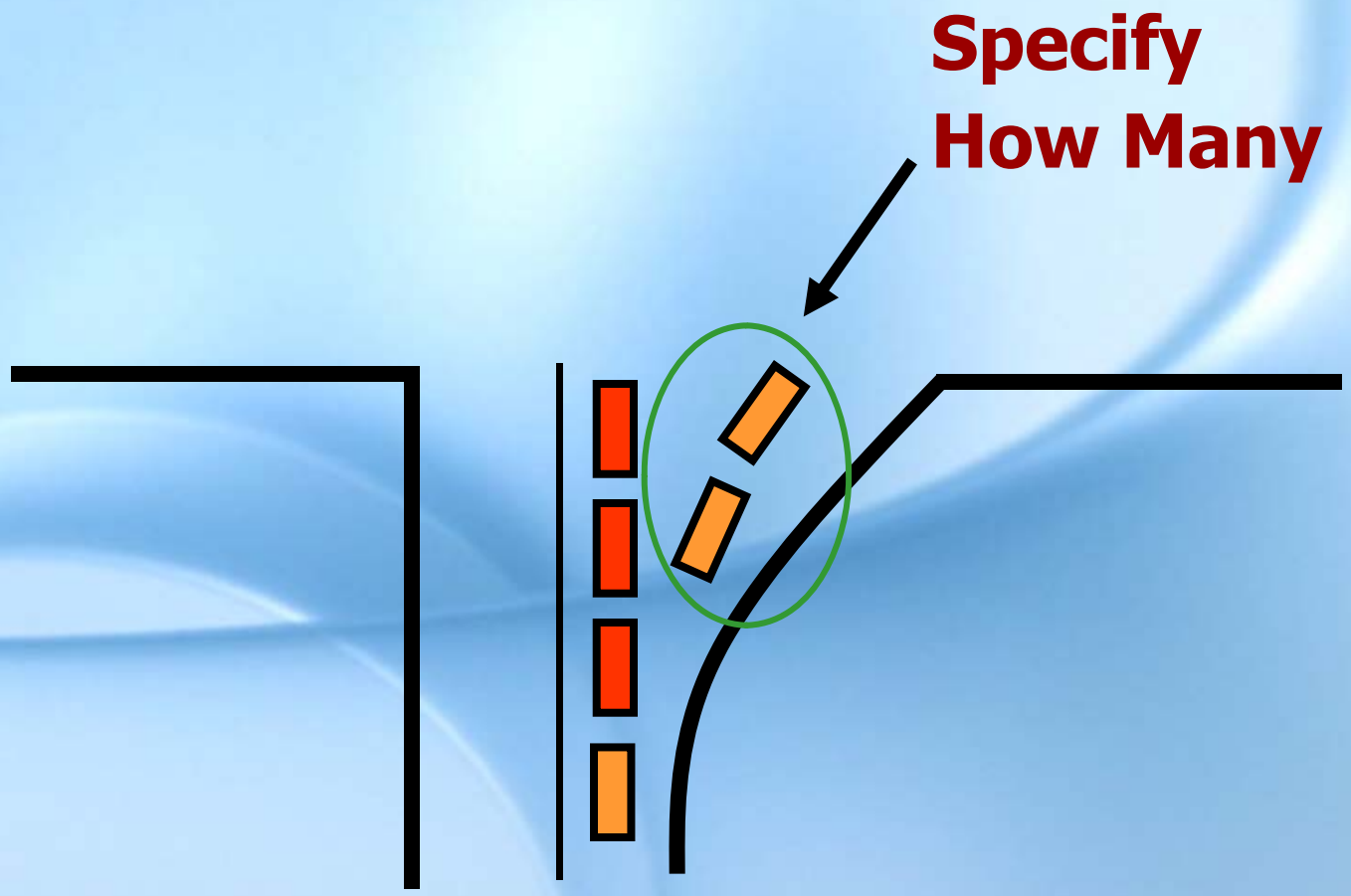


S2–Two-Stage Process *(continued)*

Enter Storage Capacity

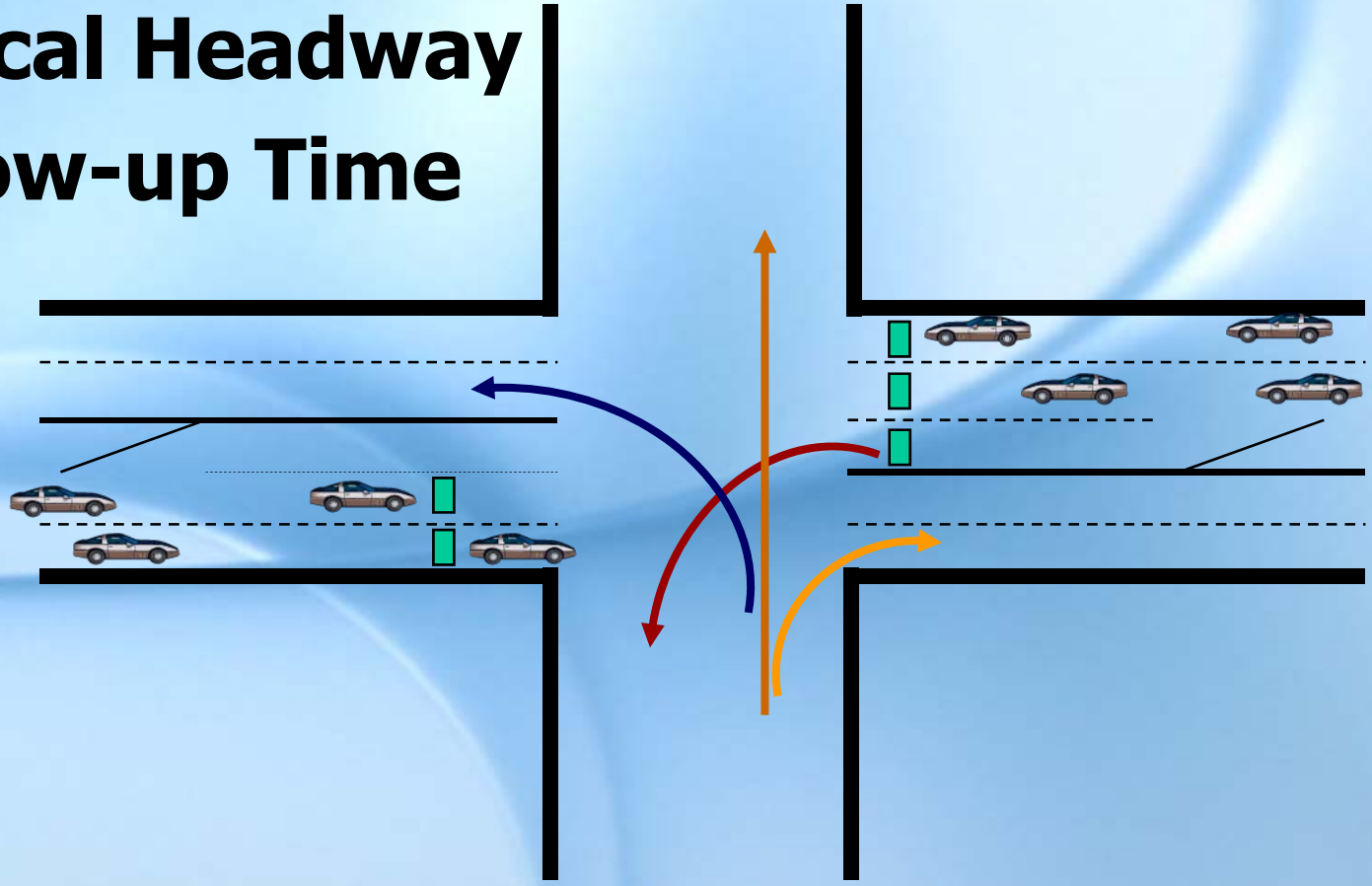


S2–Flared Approaches



S2–Model Parameters

- Critical Headway
- Follow-up Time

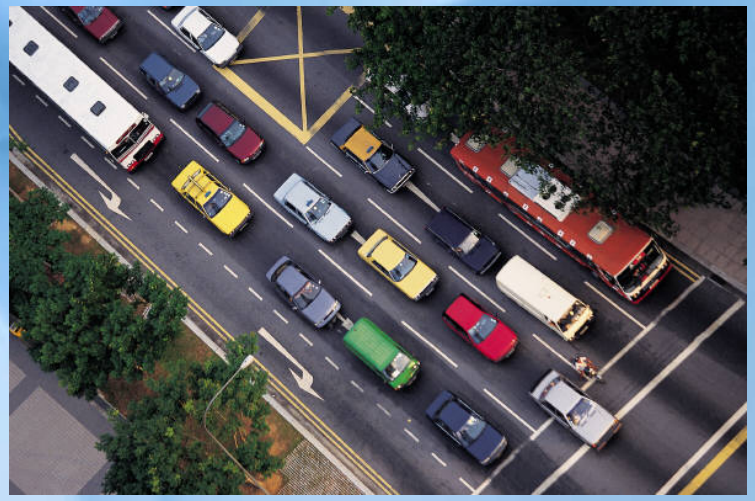


Session 3: Isolated Signals

- Overview of Theory
- PASSER V Input Data Needs
- Input Data Considerations
- Signal Exercise

S3–PASSER V Data Needs

- **Turning Movement Counts (TMC)**
  - ✓ **Collect 15-Minute Data and Calculate PHF**
  - ✓ **AM, PM, and Off-Peak**
  - ✓ **Collect Vehicle Mix Information**
- **Can Apply Growth Rates to Older Counts as Long as Traffic Patterns Haven't Changed**



S3–PASSER V Data Needs
(continued)

- Number of Lanes
- Lane Use
- Lane Widths
- Turn Bays and Lengths

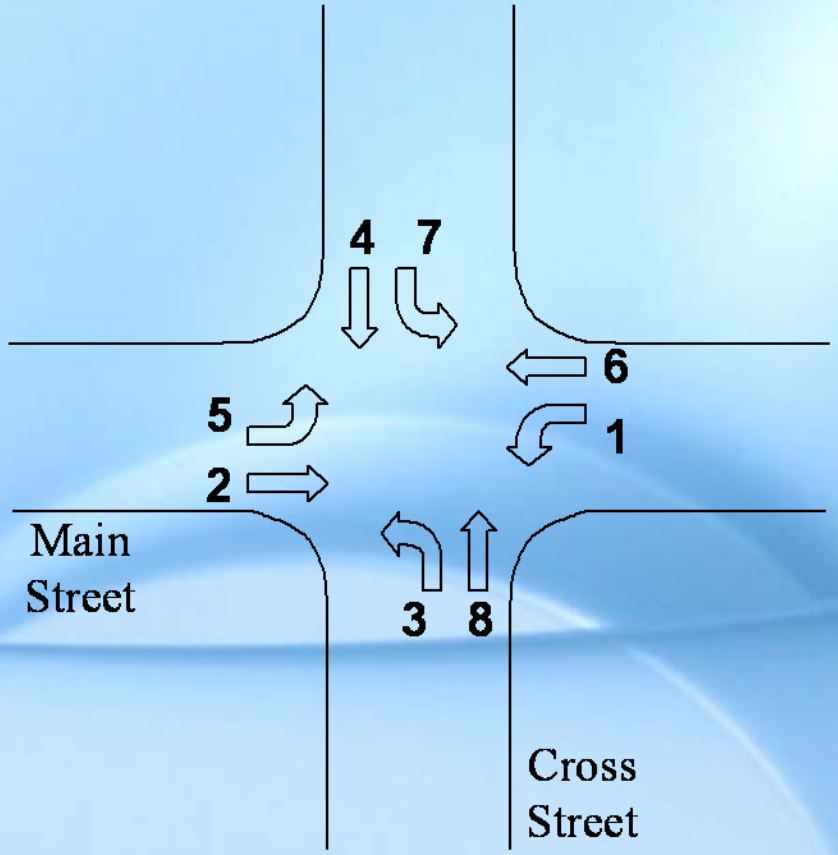
S3–Input Considerations

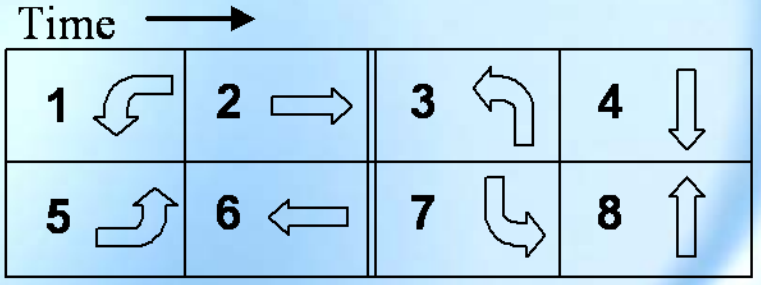
- **Left-turn Treatment**
  - ✓**Number of Opposing Lanes**
  - ✓**Overlapping Turning Paths (may need to split phase)**
  - ✓**Type of Signal Heads (3, 4, or 5 Section)**
- **Pretimed, Semi-actuated, or Fully Actuated**
- **Priority or Preemption**

S3–Performance Data

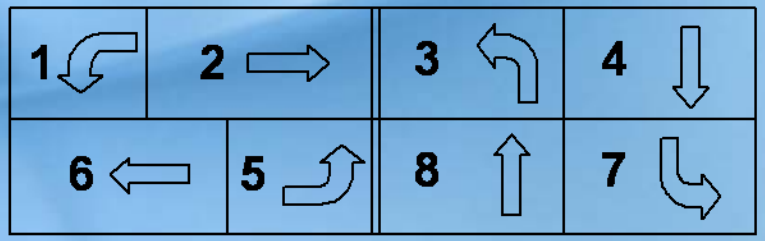
- Delay, Stops, Queue Information for Existing Conditions
- Collection Can Be Costly

S3–NEMA Phase Numbering



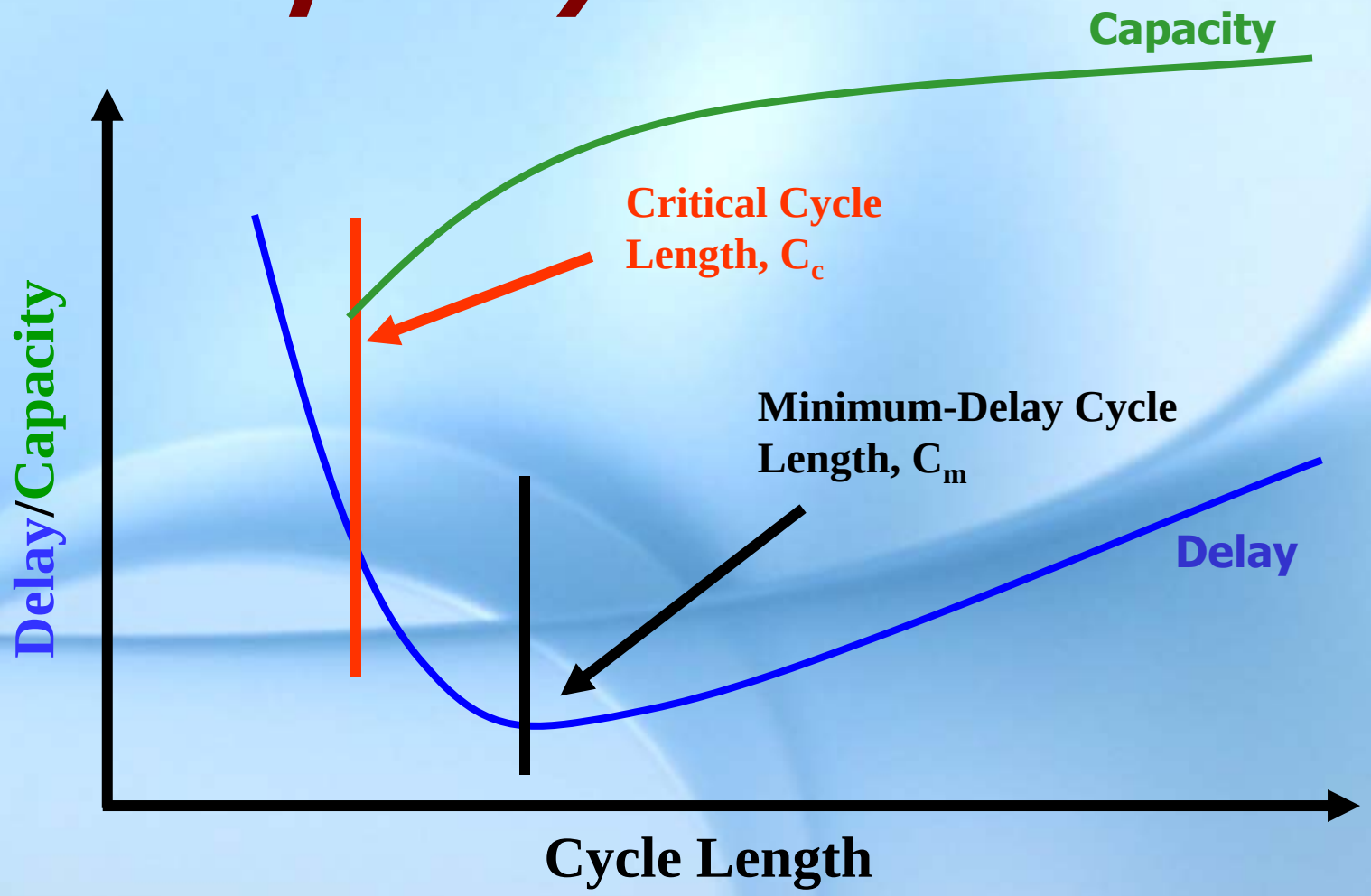


NEMA Dual-Ring Phasing
(leading lefts, no overlap)

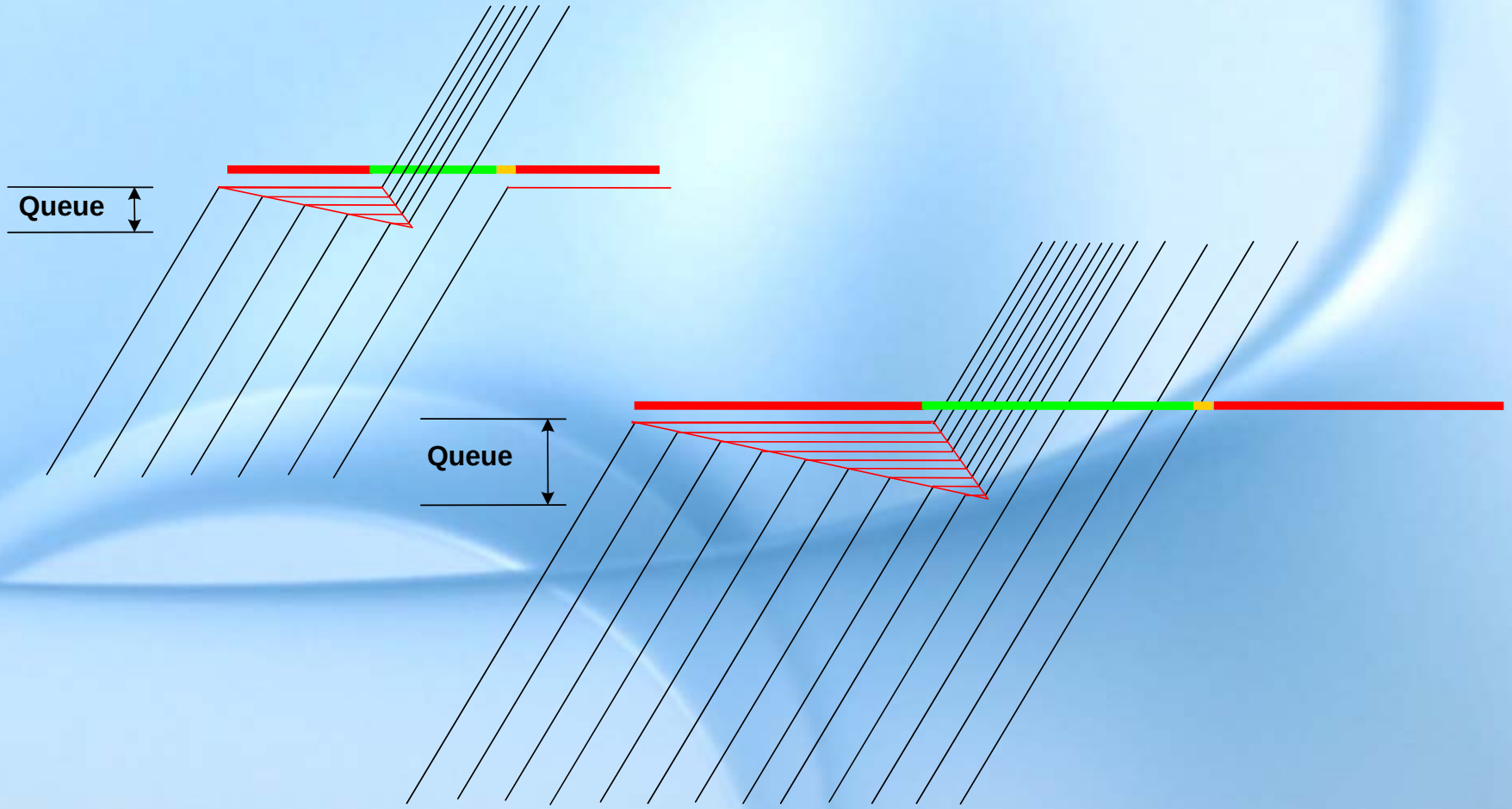


Main Street Lead-Lag,
Cross Street "Split Phased"

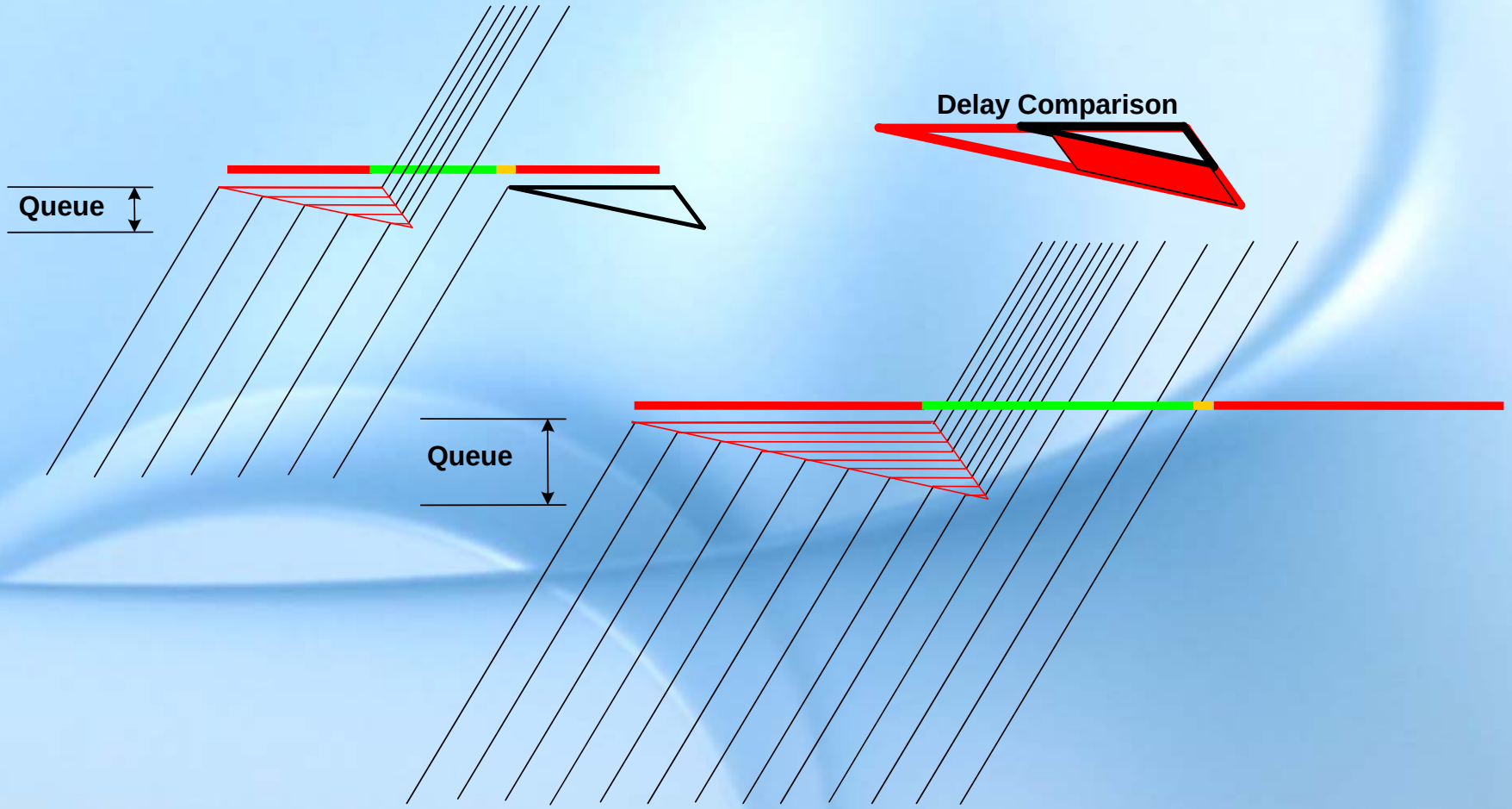
S3–Cycle Length vs. Delay and Capacity



S3–Cycle Length vs. Delay and Stops



S3–Cycle Length vs. Delay



S3–Timing Isolated Signals

- **Select Best Timings**
  - ✓**Cycle**
  - ✓**Splits (or max, min, gap setting)**
  - ✓**Clearance Intervals**
- **To Provide**
  - ✓**Safe**
  - ✓**Efficient Operation**

S3–Safety Issues

- Space Conflicts inside Intersection
  - ✓Use of Split Phasing
- Minimum Greens
  - ✓Based on Driver Expectancy
- Vehicle Clearance Intervals
- Pedestrian Requirements
- Yellow Trap

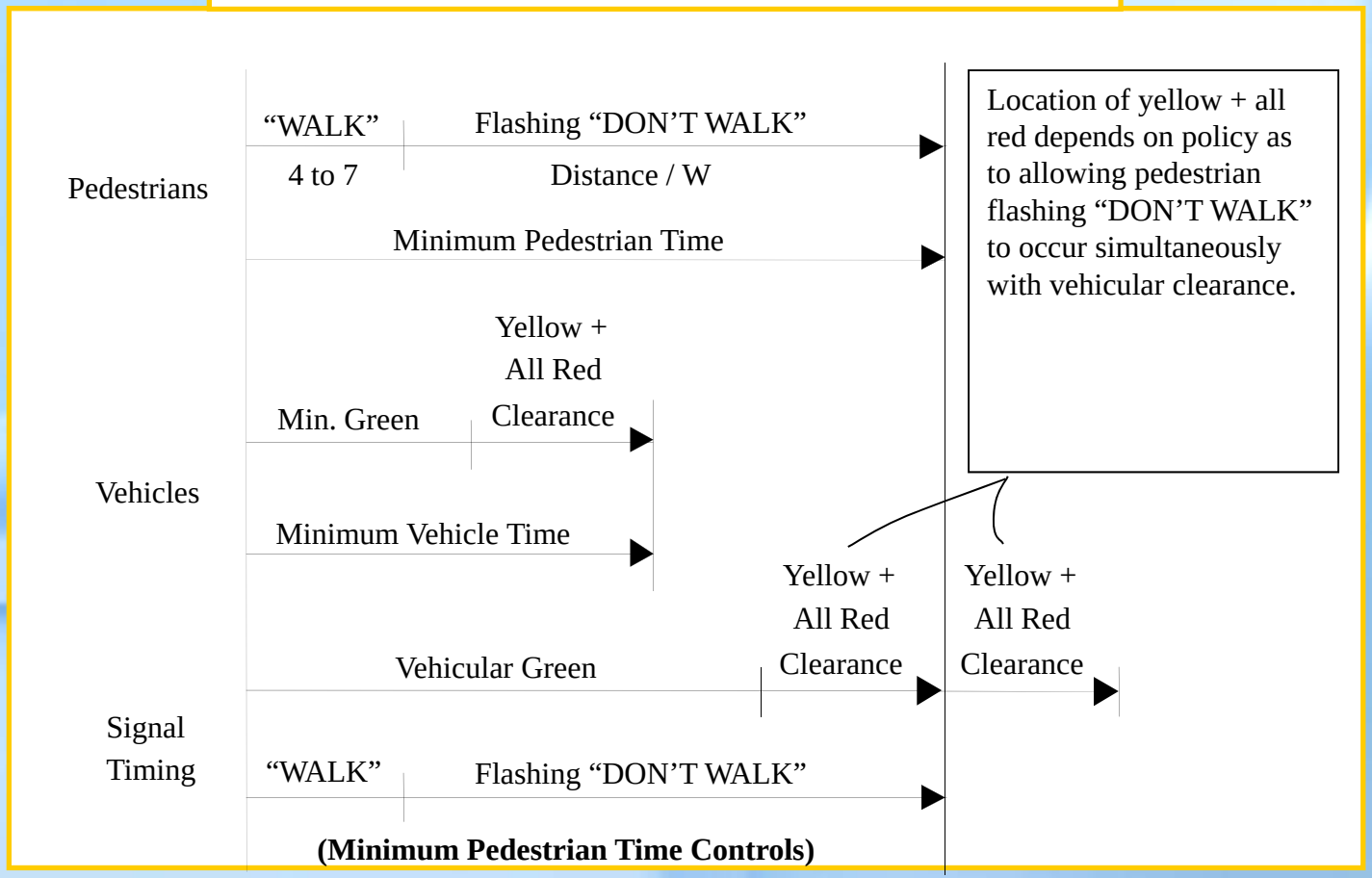
S3–Clearance Intervals

- **Proper Settings Avoid a "Dilemma Zone"**

Speed mph	Yellow Change sec (level grade)		Red Clearance sec (60' wide crossing)
25	2.84		2.18
35	3.57		1.55
45	4.31		1.21
55	5.04		0.99
65	5.78		0.84

S3–Pedestrians

$$G_p = (4 \text{ to } 7 \text{ seconds}) + \frac{\text{Distance}}{W}$$



S3–Best Isolated Operation

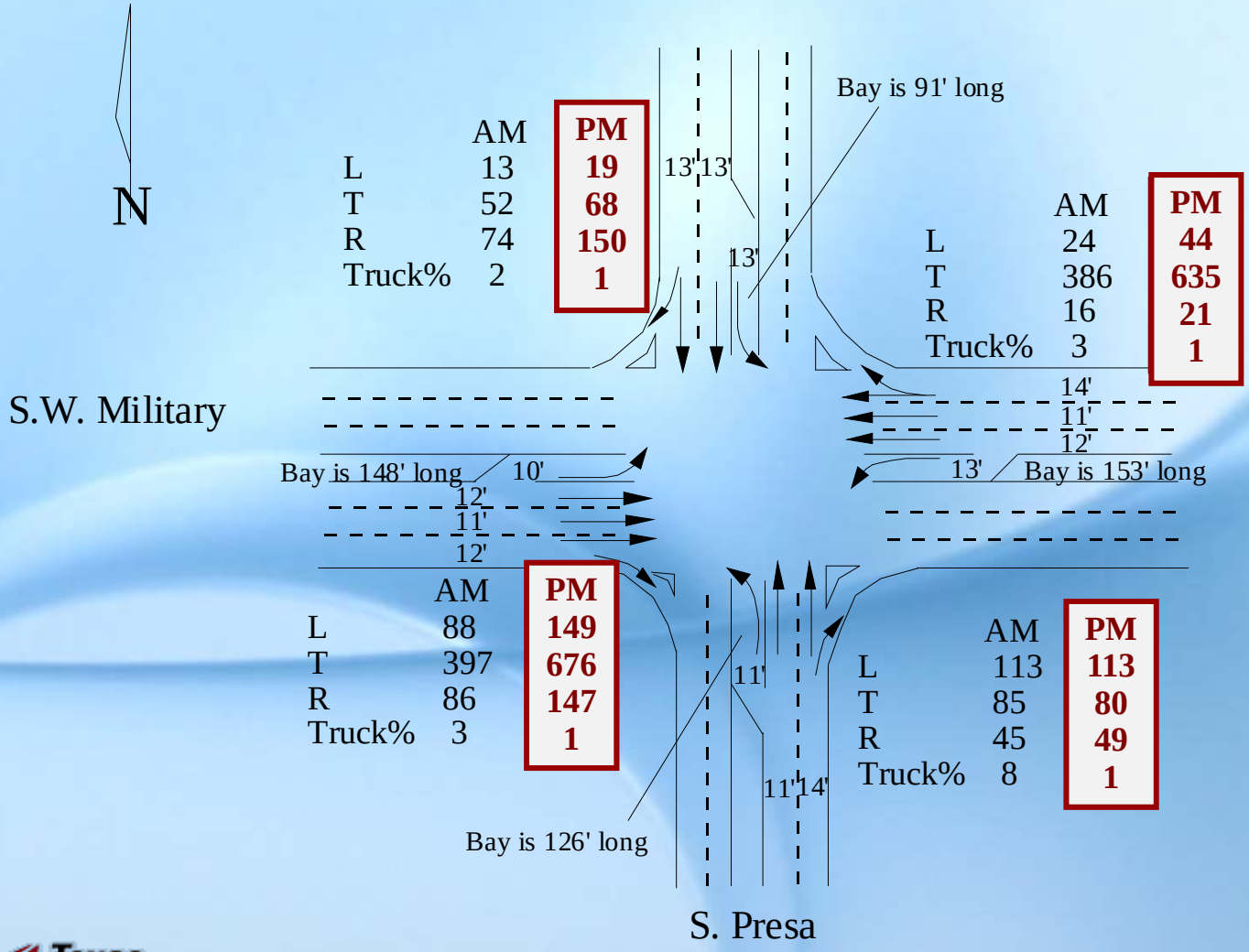
- What is Good Operation?
  - ✓Minimum Delay
  - ✓Shortest Queues per Cycle
  - ✓Minimum Stops
  - ✓Compromised Combination
- User Decides Based on Situation
  - ✓Approach Speeds
  - ✓Traffic Counts
  - ✓Driver Perception

S3–Isolated Signal Exercise

- Draw an Isolated Signal
- Enter Data
- Analyze

S3–Intersection Data (User Guide, p. 91)

S.W. Military at S. Presa, San Antonio, Texas



S3–Data Entry

- Draw Links
- Define Lanes
- Enter PM-peak Volumes
  - ✓i.e., 149, 676, and 147 for EB
- Select Movement Type
  - ✓EB and WB Prot (why?)
  - ✓NB and SB Prot/Perm

S3–Data Entry *(continued)*

- **Adjust Right-turn Volumes for RTOR**
- **Overlap (Yes for Lefts)**
- **Min Splits**
  - ✓**Peds if No Buttons (Assumed)**
    - » NB: 7+ (12+11+12+13+12+11+14)/4 = 28.25 ≈ 29 sec.
  - ✓**EB, WB, NB, SB: 23, 23, 29, 29**
  - ✓**Clearance Times**

S3–Data Entry *(continued)*

- Adjustments to Flows
- Trucks
- Ideal Saturation Flow
- Click Update Button

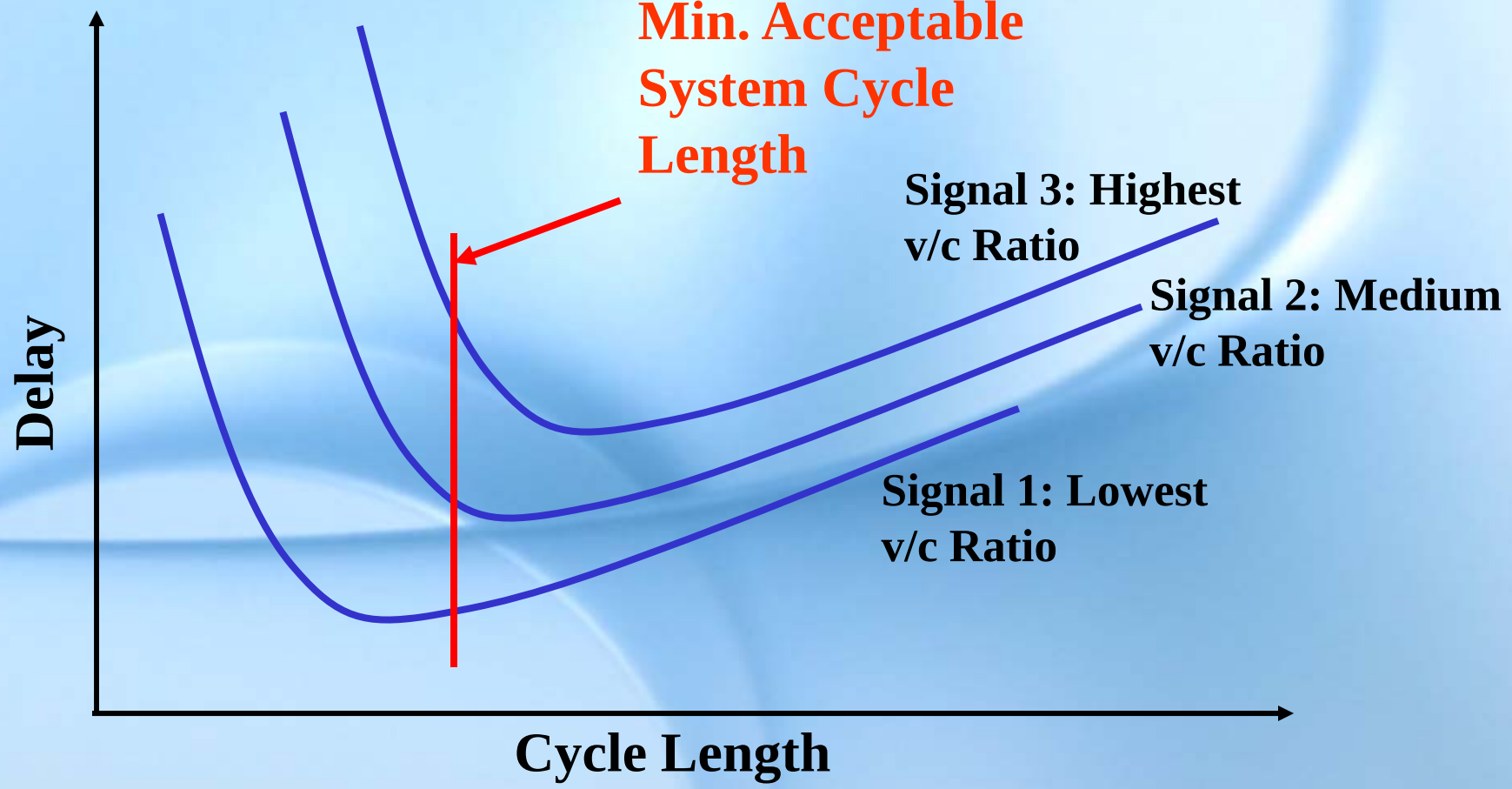
S3–Analysis/Results

- Delay vs. Cycle Analysis
- Controller: Ring-Barrier Display
- MOEs

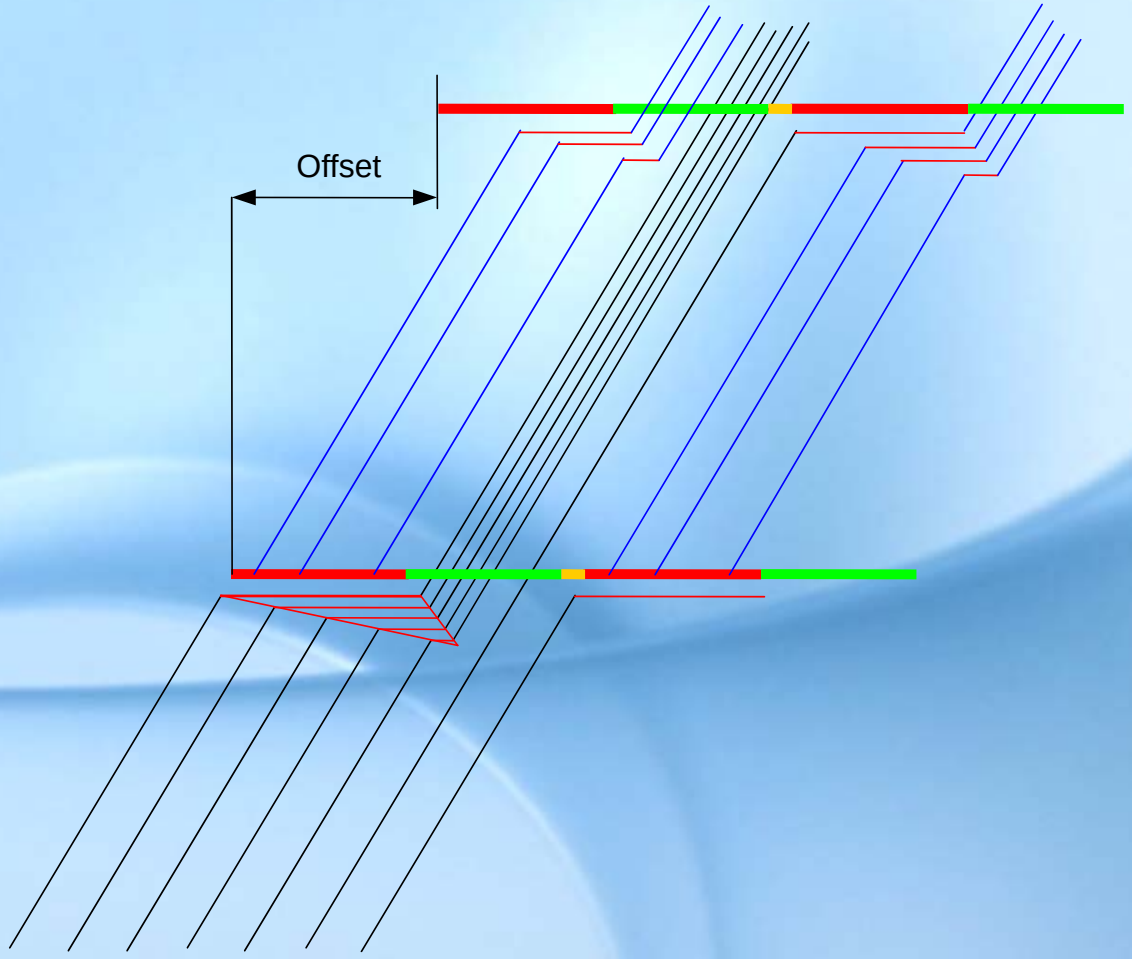
Session 4: Signal Systems

- **Overview:**
  - ✓ **Engineering Theory**
  - ✓ **Analysis Tools**

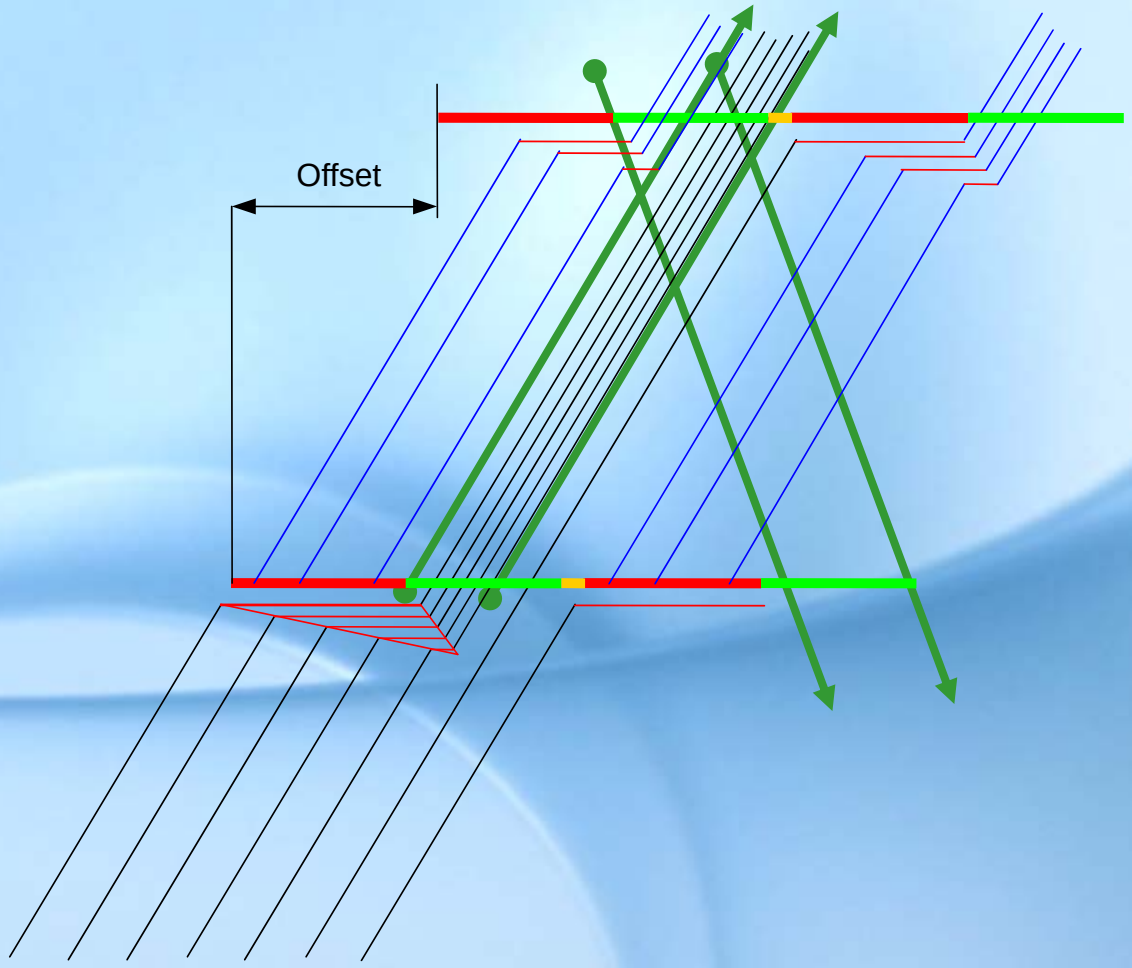
S4—Flow Stability between Adjacent Systems



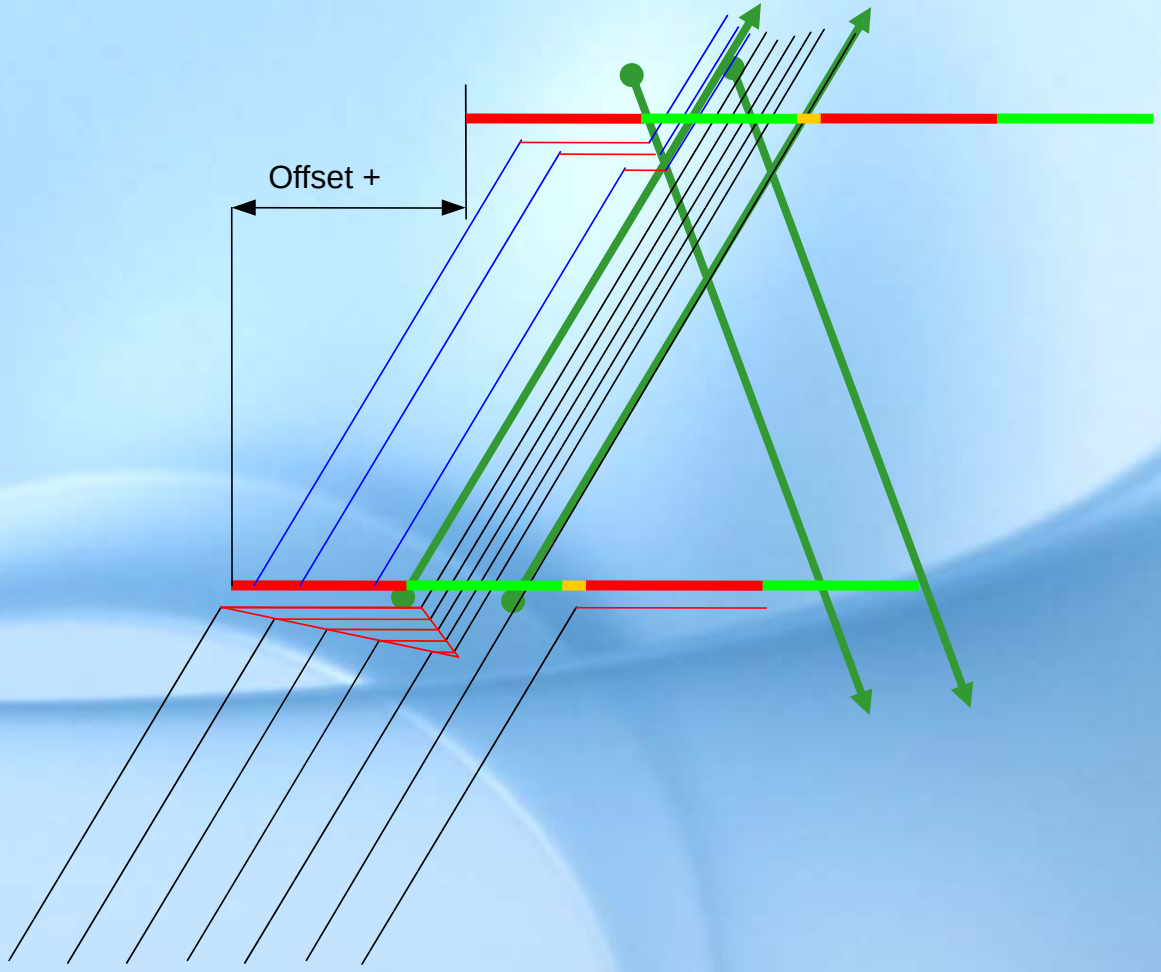
S4–Signal Offset and Flow between Adjacent Signals



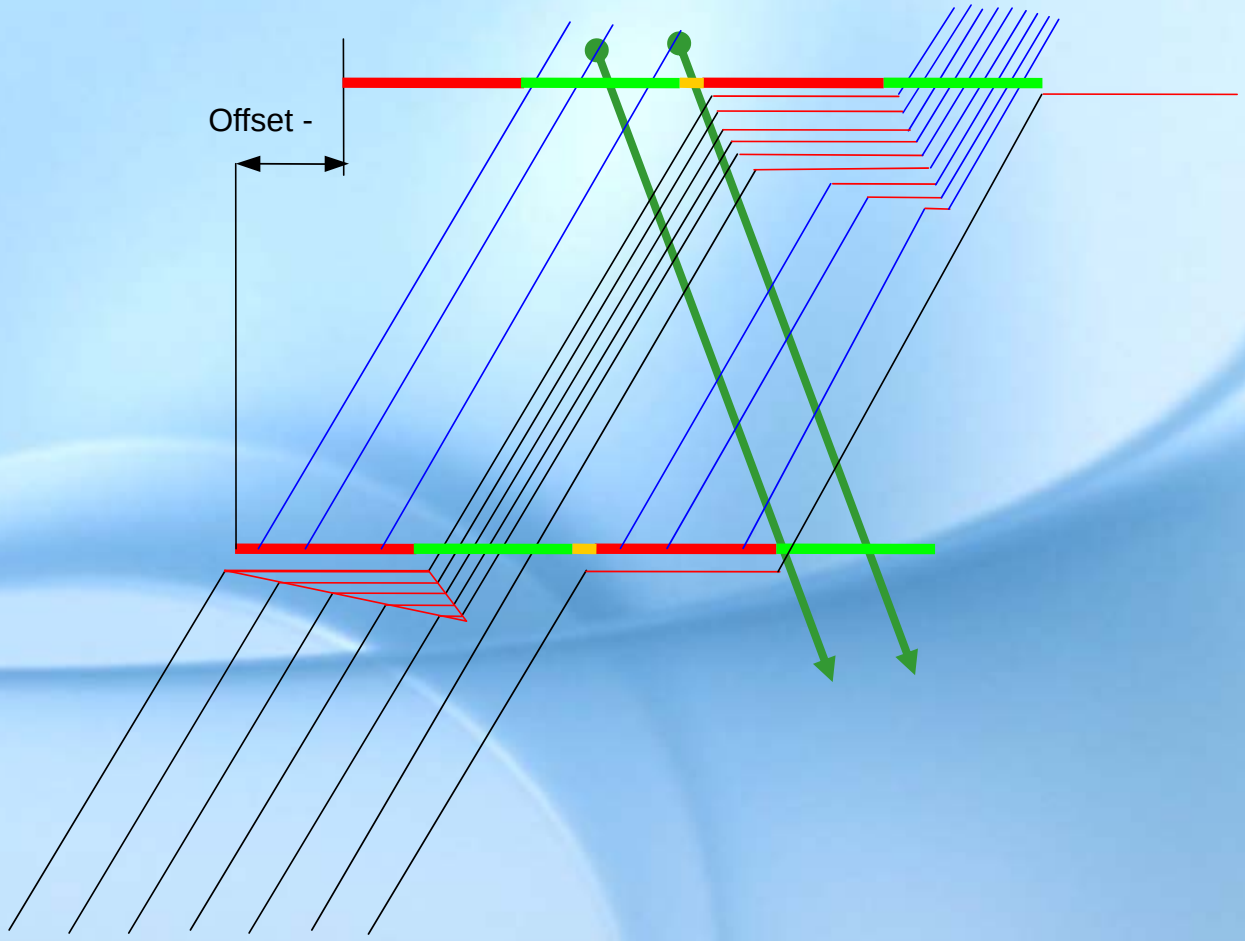
S4–Flow vs. Bands



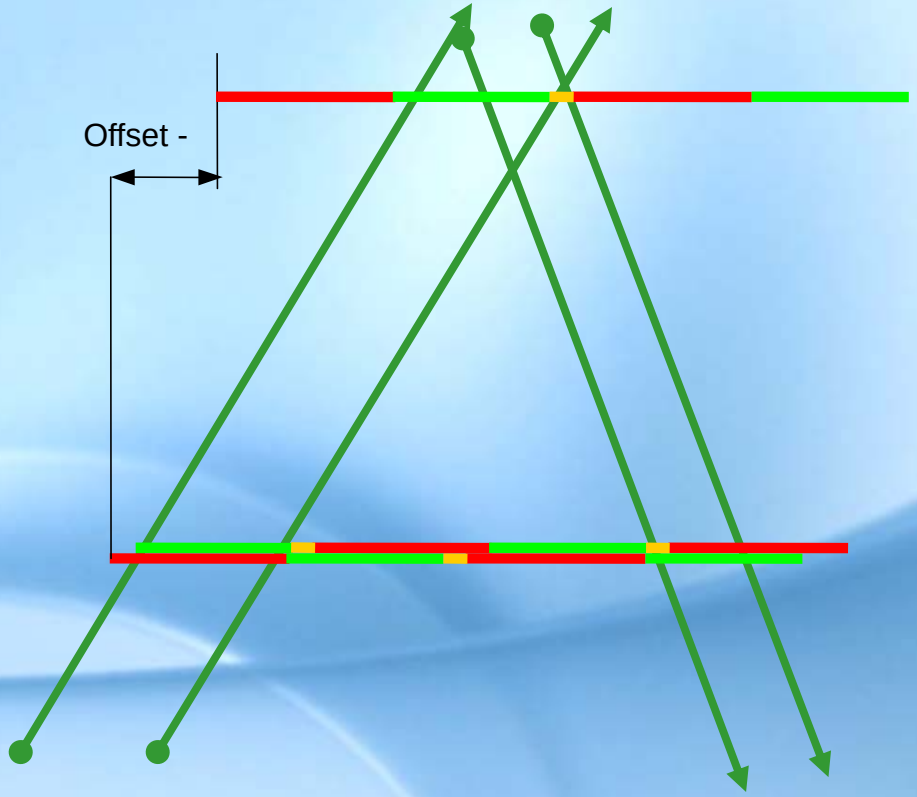
S4—Effects of Changes in Offset



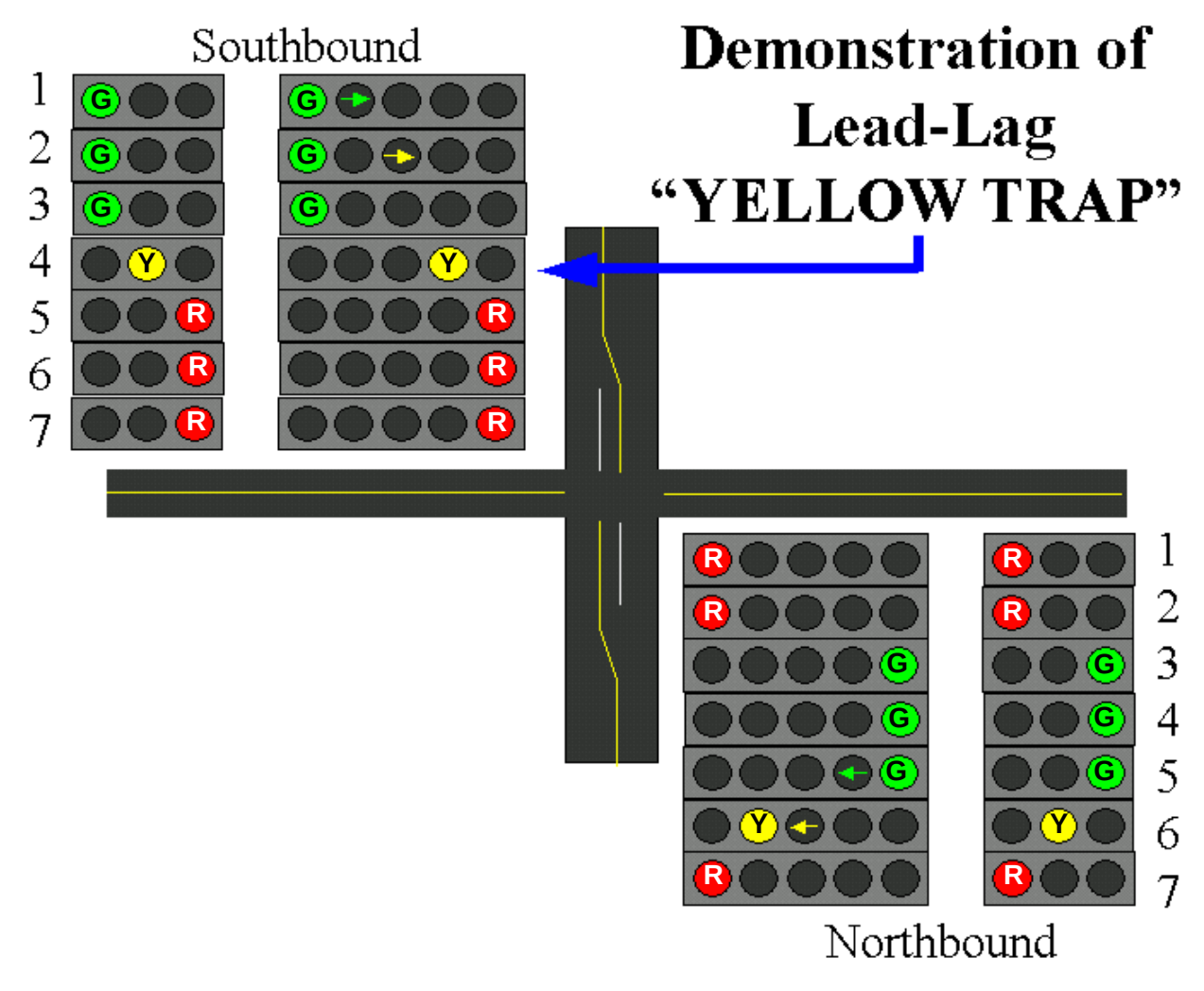
S4—Cannot Get Two-way Bands? Change Phasing!



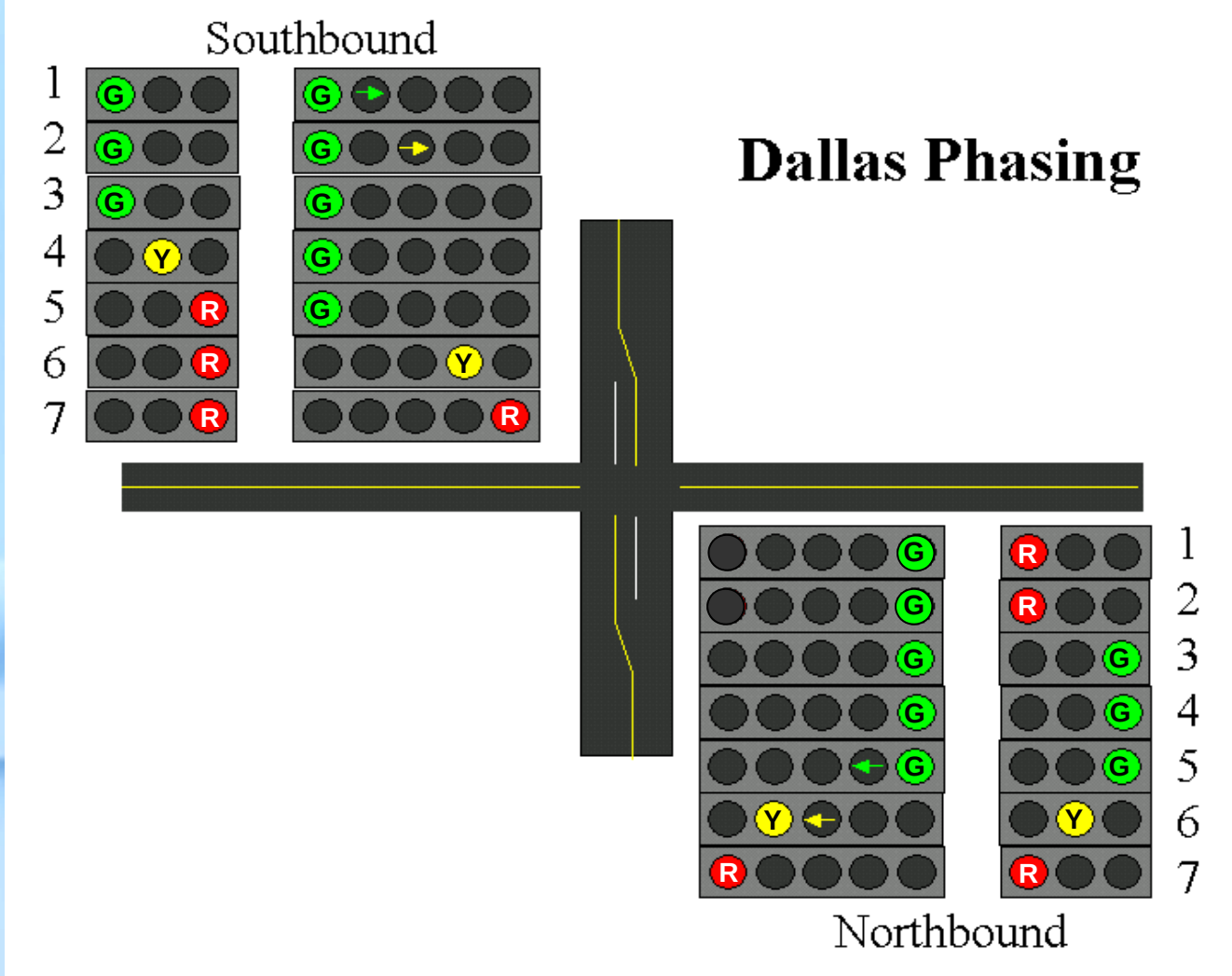
S4–Changing Phasing Can Improve 2-way Progression



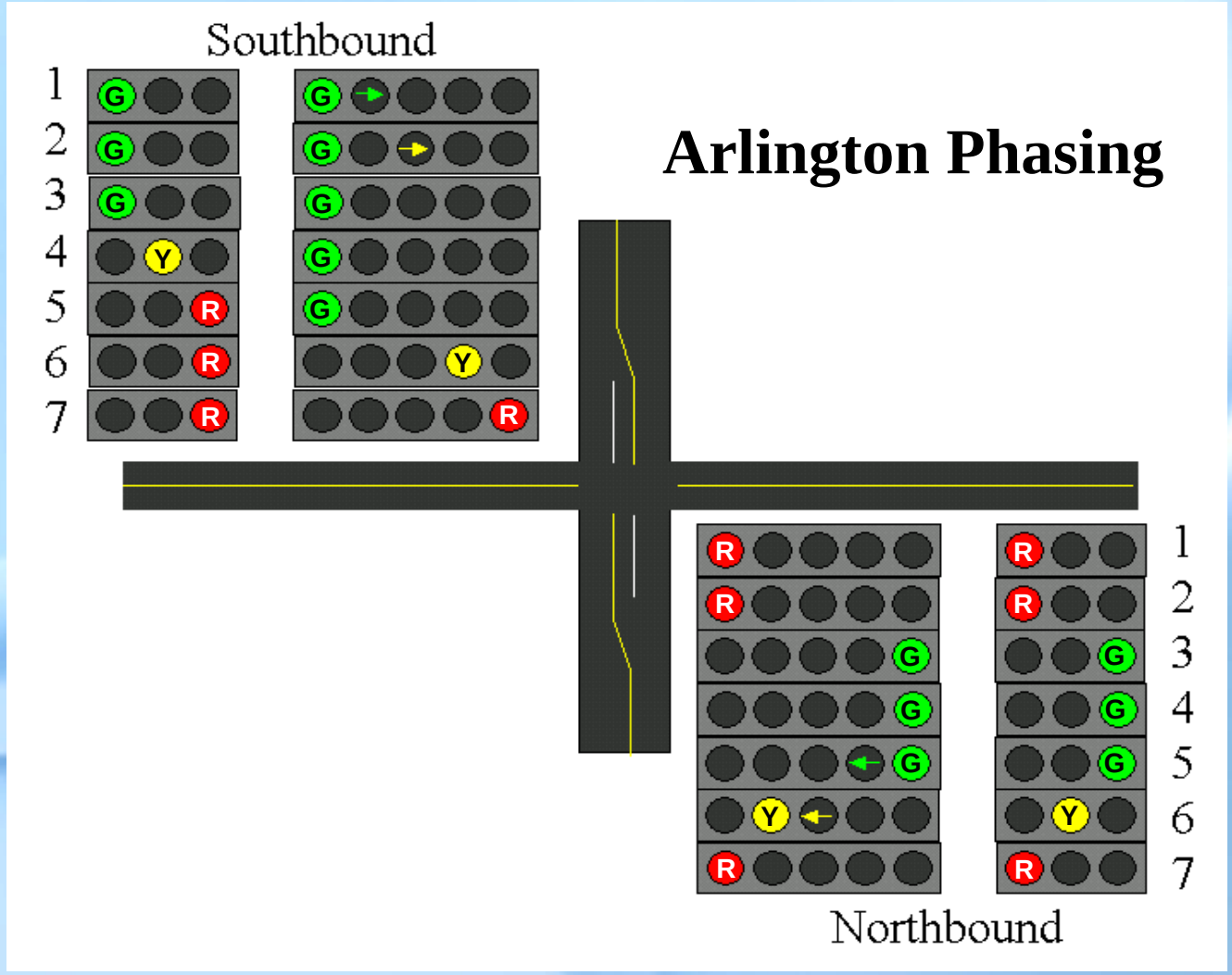
S4–Yellow Trap



S4–Yellow Trap *(continued)*



S4–Yellow Trap *(continued)*



S4–Timing Adjacent Signals

- **Objectives of Coordination**
  - ✓ **Provide/Maintain Safety**
  - ✓ **Maintain Stable Flow**
  - ✓ **Minimize Systemwide Delay**
  - ✓ **Minimize Queues and Spillback**
  - ✓ **Maximize System Throughput**
  - ✓ **Minimize Number of Stops**
  - ✓ **Maximize Arterial Progression**

S4–Types of Models

- **Traffic Simulation Model**
  - ✓ **Evaluates a Specified Scenario**
  - ✓ **Generates Performance Measures**
- **Optimization Model**
  - ✓ **Systematically Generates Scenarios**
  - ✓ **Evaluates Using Simulation**
  - ✓ **Selects the Best Scenario**
  - ✓ **Usually Applicable to Traffic Signals**

S4–Simulation Models

- **Microscopic**
  - ✓ **Keeps Track of Each Vehicle**
  - ✓ **Time Consuming**
- **Mesoscopic**
  - ✓ **Analyzes Flow Profiles**
  - ✓ **Faster Calculations**
- **Macroscopic**
  - ✓ **Analyzes Platoons**
  - ✓ **Fastest Calculations**

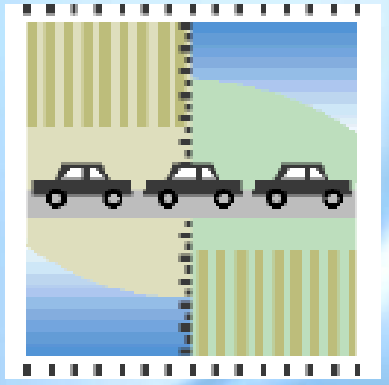
S4–Simulation Models *(continued)*

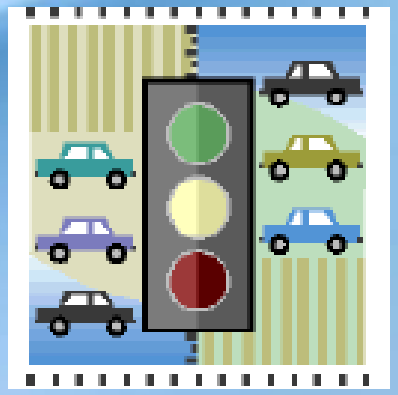
- **Microscopic**
  - ✓ **Keeps Track of Each Vehicle**
  - ✓ **Time Consuming**
- **Mesoscopic**
  - ✓ **Analyzes Flow Profiles**
  - ✓ **Faster Calculations**
- **Macroscopic**
  - ✓ **Analyzes Platoons**
  - ✓ **Fastest Calculations**

- **Stochastic**
- **Deterministic**

S4–Simulation Accuracy

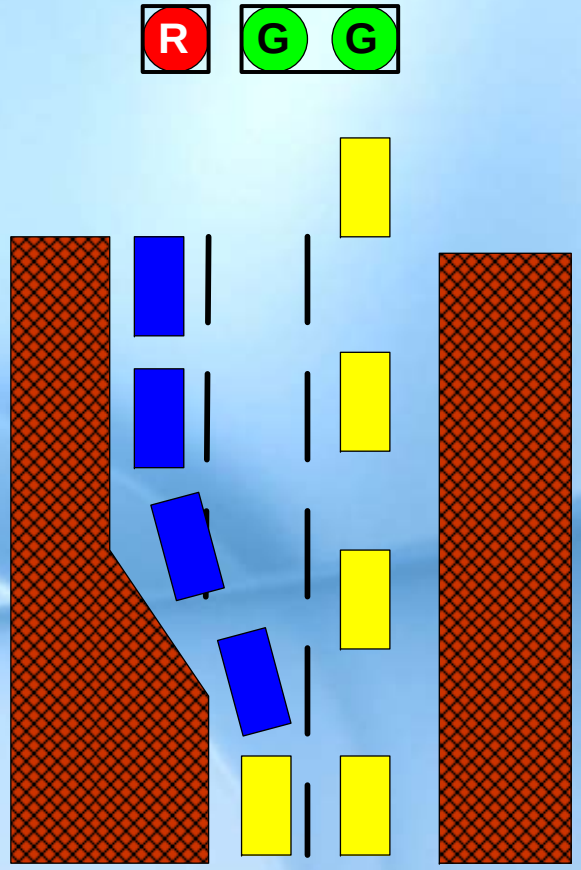
- **Realistic Queues**
  - ✓**Microscopic: CORSIM, Vissim, SimTraffic**
  - ✓**Mesoscopic: new T7F, PASSER V, Synchro**
- **Upward Queue Stack**
  - ✓**Mesoscopic: old T7F, S5 and P3**
  - ✓**Macroscopic: P2, P4**



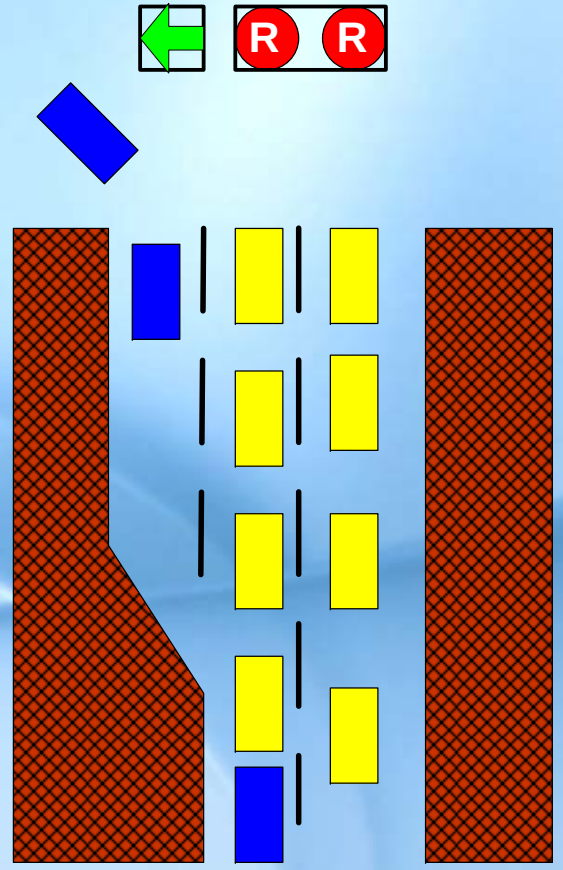


S4–Spillback & Starvation

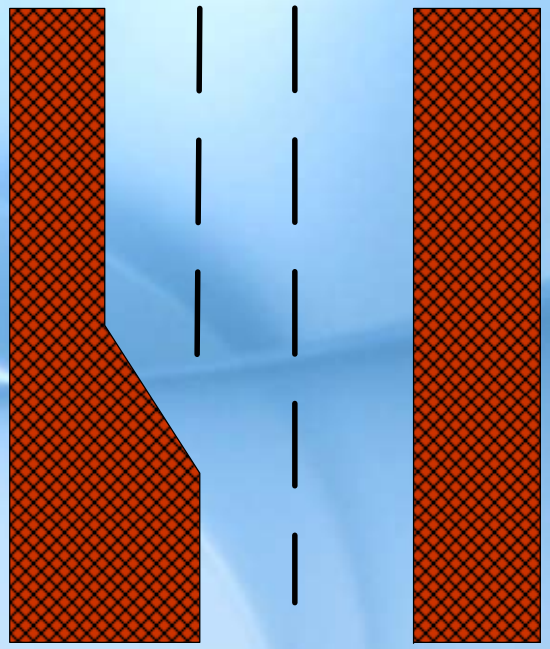
S4–Blocking and Starvation



S4—Blocking and Starvation
(continued)



S4–Starvation May Not Be Bad (Unused Capacity)



S4–Optimization Criteria

- Maximize Arterial Progression
- Minimize Systemwide Delay
- Minimize Stops
- Minimize Queues
- Maximize Throughput
- Minimize Blocking and Spillback

S4–Magnitude of Problem

Fixed Cycle=100 Sec

1:

2-Phase Signals

2:

3: 2a with Phase Optimization

1. 100 Plans

2. Depends

- 200, or
- 10,000 Plans

3. 200 X 64 = 12,800 Plans

S4–Optimization Methods

- Exhaustive Search
- Smart Search Techniques
  - ✓Hill-climbing
  - ✓Heuristic
  - ✓Mathematical Programming
  - ✓Genetic Algorithms
- Most Signal-Timing Programs Use a Combination

S4–Optimization Tool Types

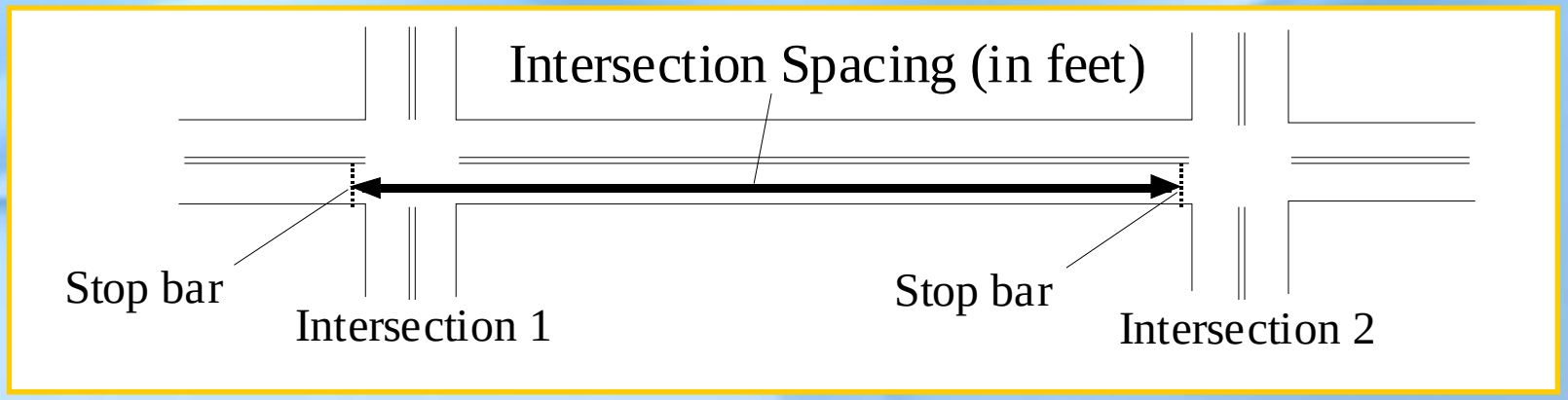
- **Delay-Based**
  - ✓**Minimizes Delay (+Qs and Stops)**
  - ✓**Evaluates/Simulates Each Plan**
  - ✓**Examples:**
    - » TRANSYT 7F: Exhaustive, Hill-climbing, GA
    - » Synchro: Exhaustive + Heuristic Search
    - » PASSER III: Exhaustive Search
    - » PASSER V: Exhaustive, GA

S4–Optimization Tool Types *(continued)*

- **Bandwidth-Based**
  - ✓**Maximizes Arterial Progression**
    - » Simple Objective Function
  - ✓**Simulates Traffic after Optimization**
  - ✓**Examples:**
    - » PASSER II: Exhaustive and Heuristic
    - » PASSER IV: Mathematical Programming
    - » PASSER V: Exhaustive, Heuristic, GA

S4–PASSER V Data Needs

- **Signal Spacing**
- **Link Speeds**
- **Types of Link**



S4–Input Performance Data

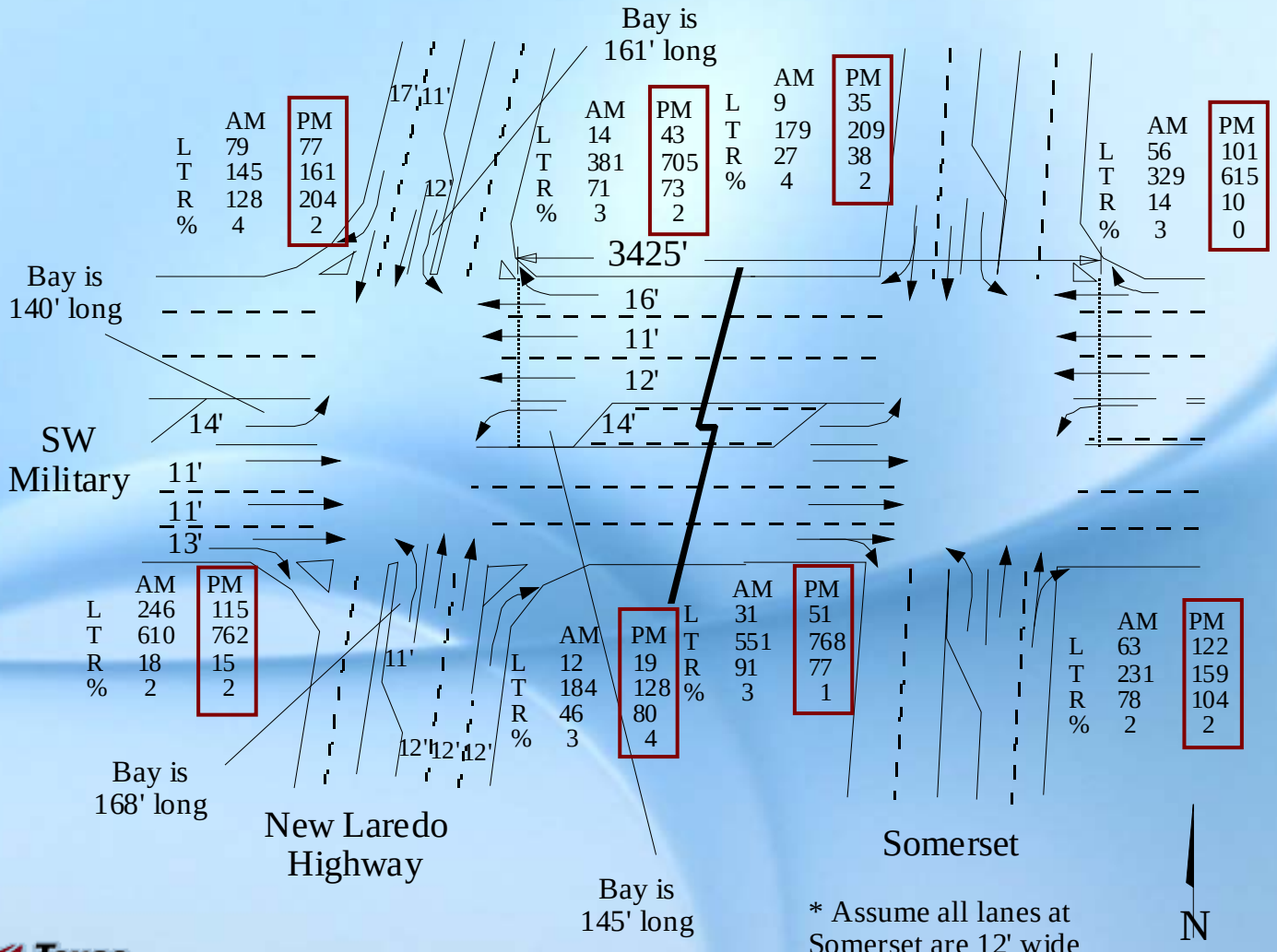
- Speed, Travel Time, or Delay Information for Existing Conditions
- May Need to Measure Speed for Use in PASSER V
- Can Be Used to Calibrate or Validate Your Base Model
- Collection Can Be Costly

Session 5: Arterial Analysis

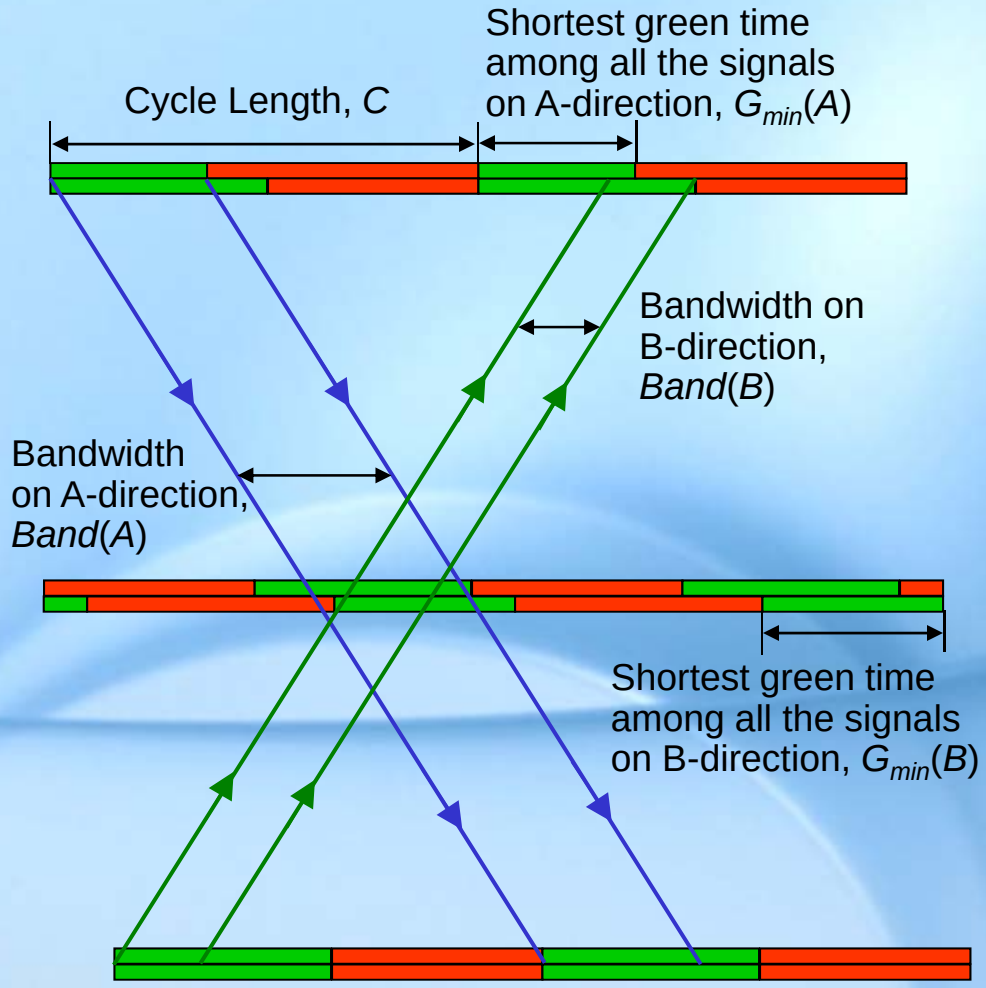
- **Arterial Exercise 1**
  - ✓ Load and Review Data
  - ✓ Apply Various Tools
  - ✓ Review/Interpret Output
- **Arterial Exercises 2 and 3**
  - ✓ TWSC Intersections
  - ✓ Sub-nets
  - ✓ Phasing Options
  - ✓ Bandwidth-constrained Delay Minimization
  - ✓ Adjusting Bands

S5–Arterial Exercise 1 (User Guide, p. 130)

S.W. Military Drive, San Antonio, Texas



S5–Performance Measures



$$Total\ Band = Band(A) + Band(B)$$

$$Efficiency = \frac{Total\ Band}{2 \times C} \times 100$$

$$Attainability = \frac{Total\ Band}{G_{\min}(A) + G_{\min}(B)} \times 100$$

S5–NTCIP Coord Phase

```
DIAL 1 SPLIT 1 PHASE PARAMETERS
PHASE.....1...2...3...4...5...6...7...8
 TIME        0   0   0   0   0   0   0   0
 MODE        0   0   0   0   0   0   0   0
MODE: 0-ACTUATED   1-COORD PH   2-MIN REC
      3-MAX REC    4-PED REC    5-MX+P REC
      6-PH OMIT    7-DUAL COORD PHASE
A-UP B-DN C-LT D-RT E-ENTER F-PRIOR MENU
```

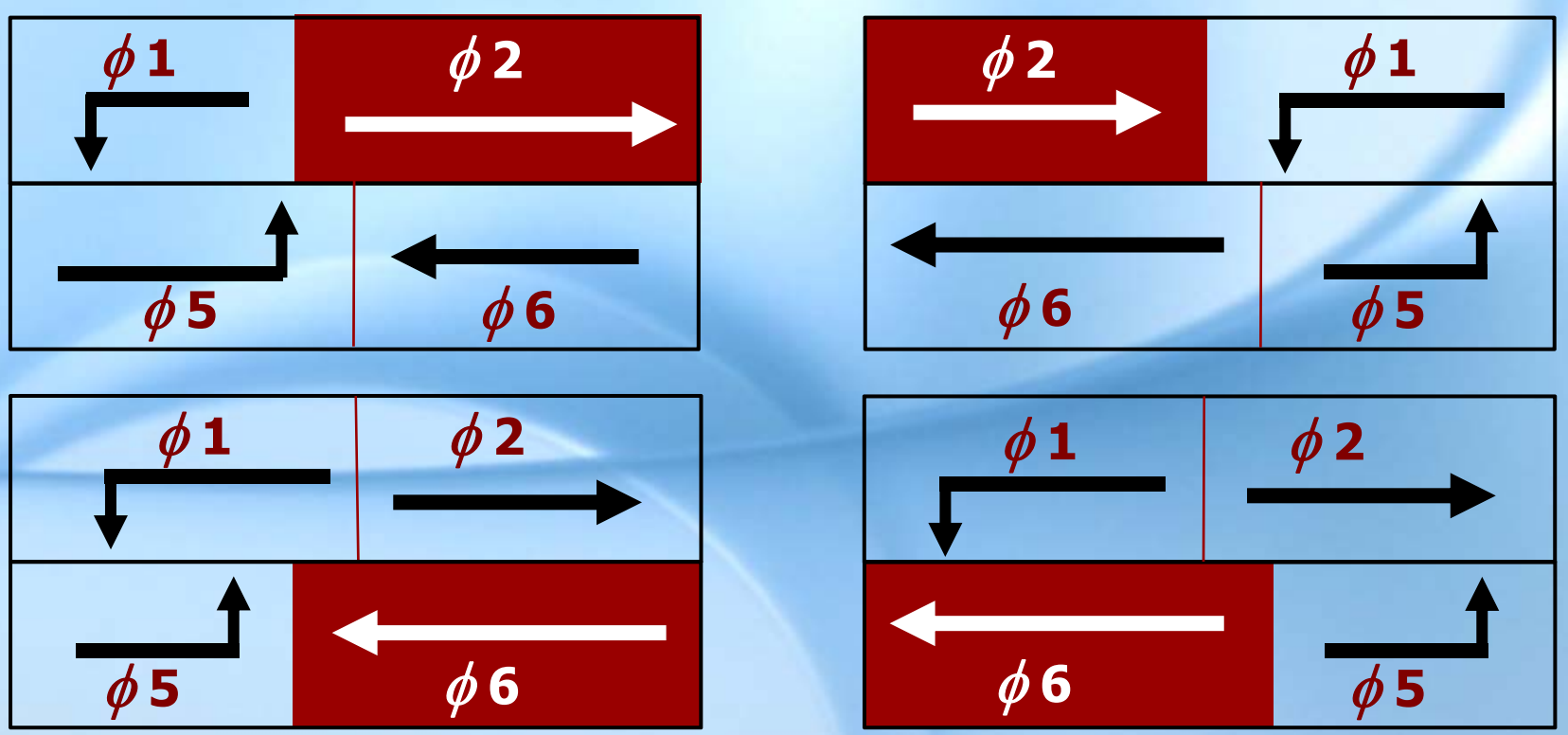
```
Spl-32 Ø..1...2...3...4...5...6...7..8 ->
Time      25  25  25  25  25  25  25 25
Coor-Ø     .   X   .   .   .   .   .  .
Mode     NON MAX NON NON NON MAX NON NON
```

S5–NTCIP Coord Phase

(continued)

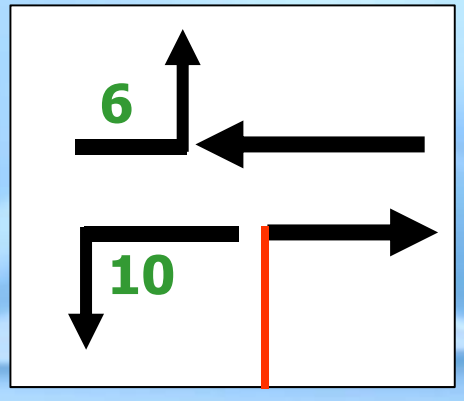
Coordinate Phase: 2

Offset Reference Phase



S5–Offset Adjustments

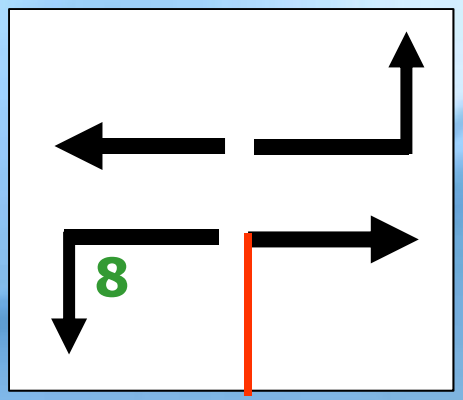
- **Lead-Lead Example**



Phase 2

Offset 10 Sec

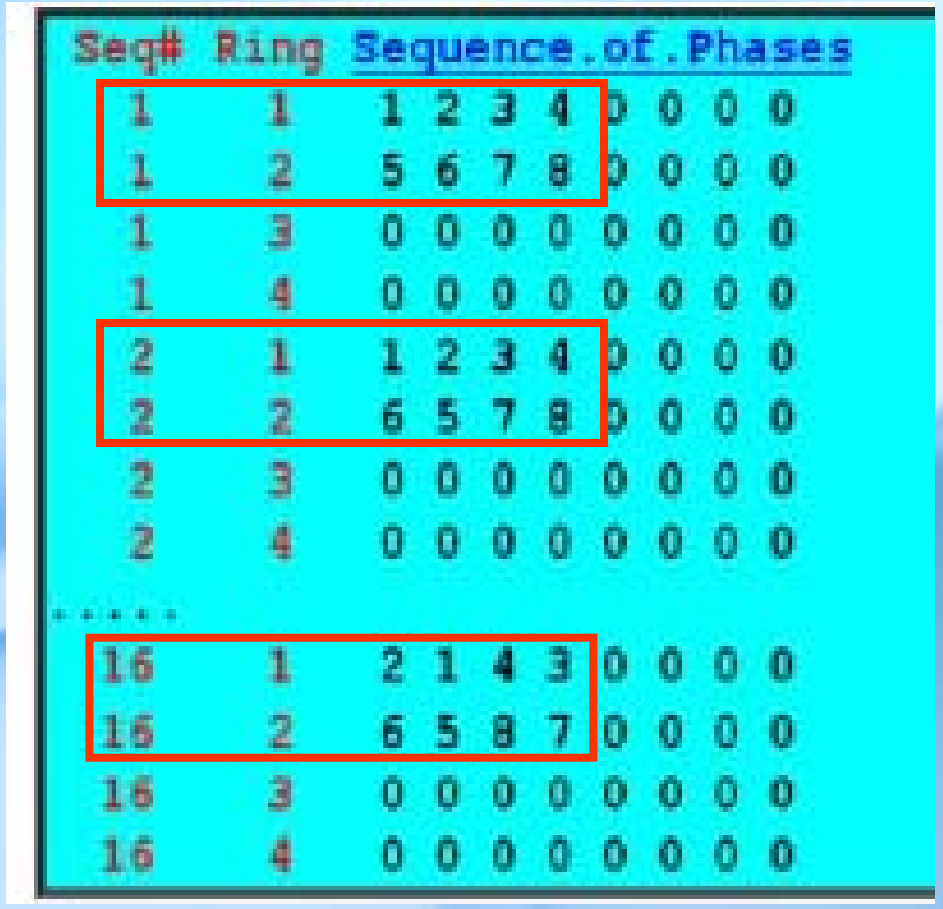
- **Lag-Lead Example**



Phase 2

Offset 10 Sec

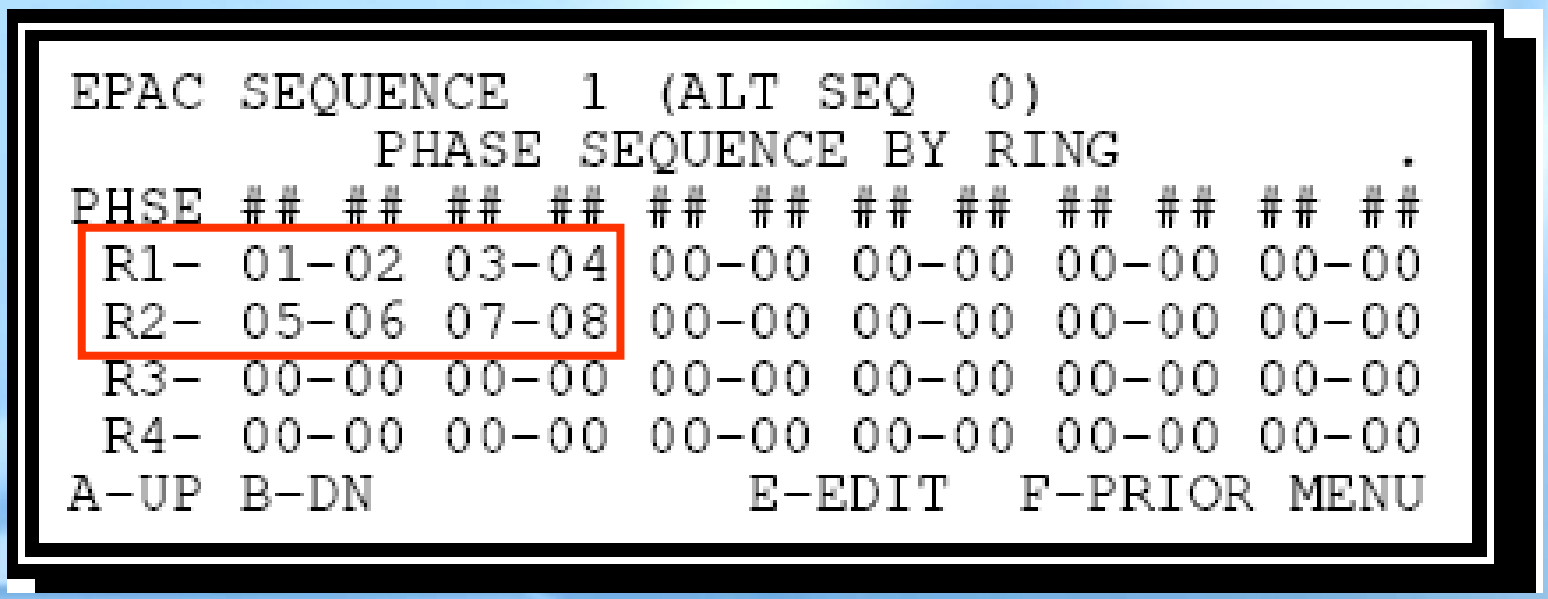
S5–Programming Sequences



Seq#	Ring	Sequence of Phases							
1	1	1	2	3	4	0	0	0	0
1	2	5	6	7	8	0	0	0	0
1	3	0	0	0	0	0	0	0	0
1	4	0	0	0	0	0	0	0	0
2	1	1	2	3	4	0	0	0	0
2	2	6	5	7	8	0	0	0	0
2	3	0	0	0	0	0	0	0	0
2	4	0	0	0	0	0	0	0	0
.....									
16	1	2	1	4	3	0	0	0	0
16	2	6	5	8	7	0	0	0	0
16	3	0	0	0	0	0	0	0	0
16	4	0	0	0	0	0	0	0	0

S5–Programming Sequences

(continued)



S5–Example Phase Sequences

Sequence Name	Ring	Phase Order	Sequence # Eagle/Naztec
Lead-Lead	1	1 2 3 4	0/1
	2	5 6 7 8	
Lag-Lead	1	1 2 3 4	1/2
	2	6 5 7 8	
Lead-Lag	1	2 1 3 4	2/3
	2	5 6 7 8	
Lag-Lag	1	2 1 3 4	3/4
	2	6 5 7 8	

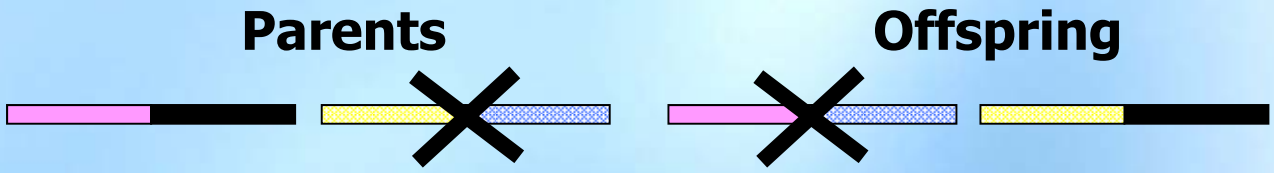
S5–How Genetic Algorithm (GA) Works

- Randomly Generate Population
- Perform Reproduction Operation
  - ✓ Select Pairs/Parents and Generate Offspring

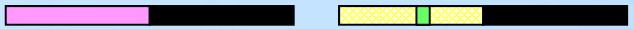
- Evaluate Each Using Simulation
  - ✓ Note Population Has Doubled

S5–How GA Works *(continued)*

- **Keep Best Half of New Population**



- **Perform Mutation Operation**

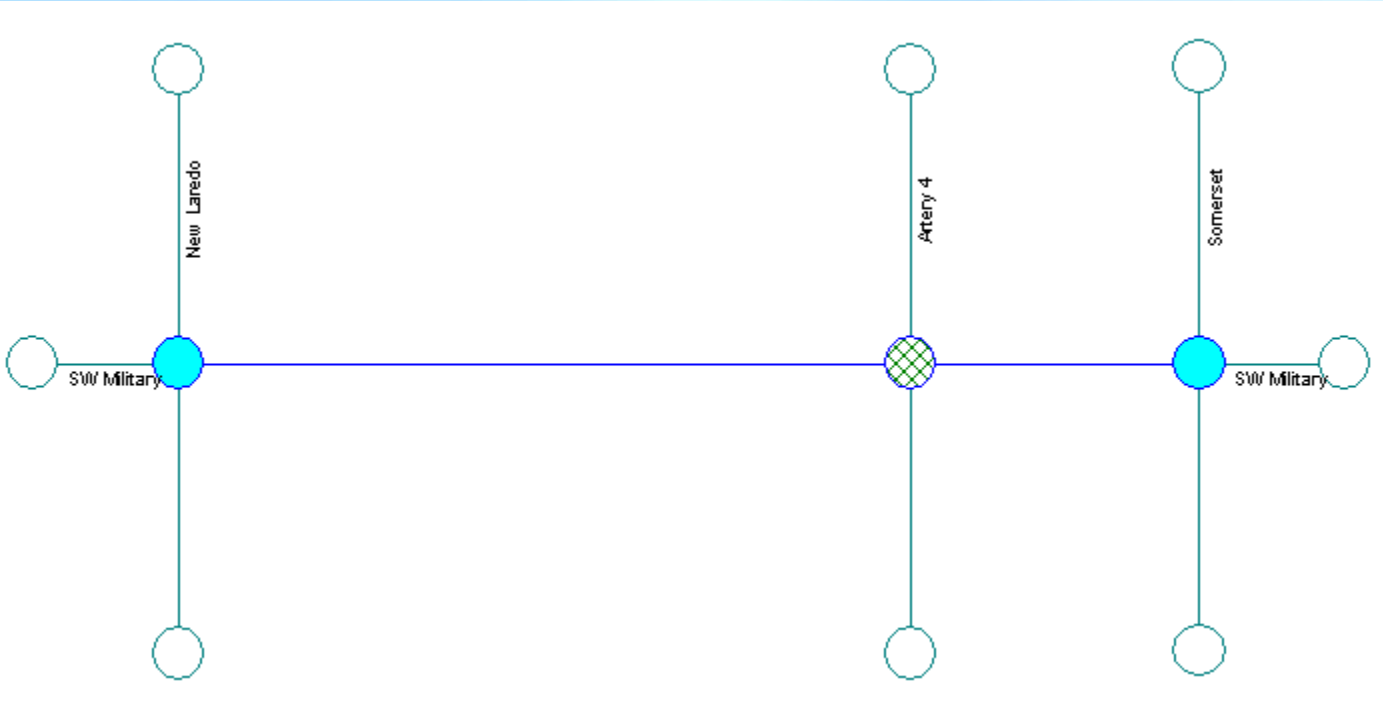


Next Generation

S5–How GA Works *(continued)*

- **Stop If**
  - ✓ **No Improvement Possible or Maximum Generations Reached**
  - ✓ **Report the Best Plan**
- **Else**
  - ✓ **Repeat Process**

S5–Arterial Exercise 2

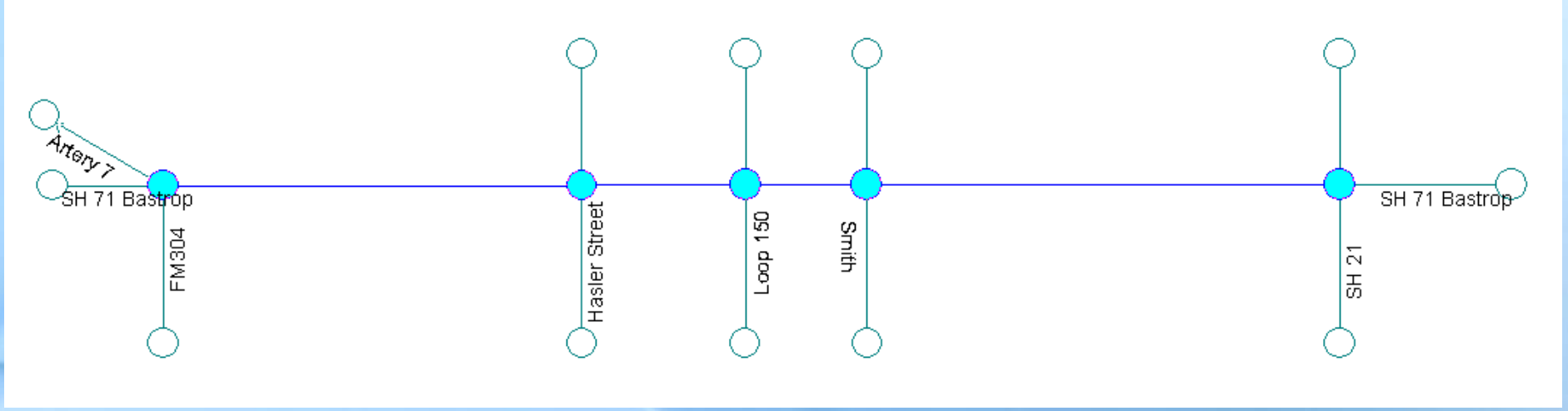


S5–More Theory

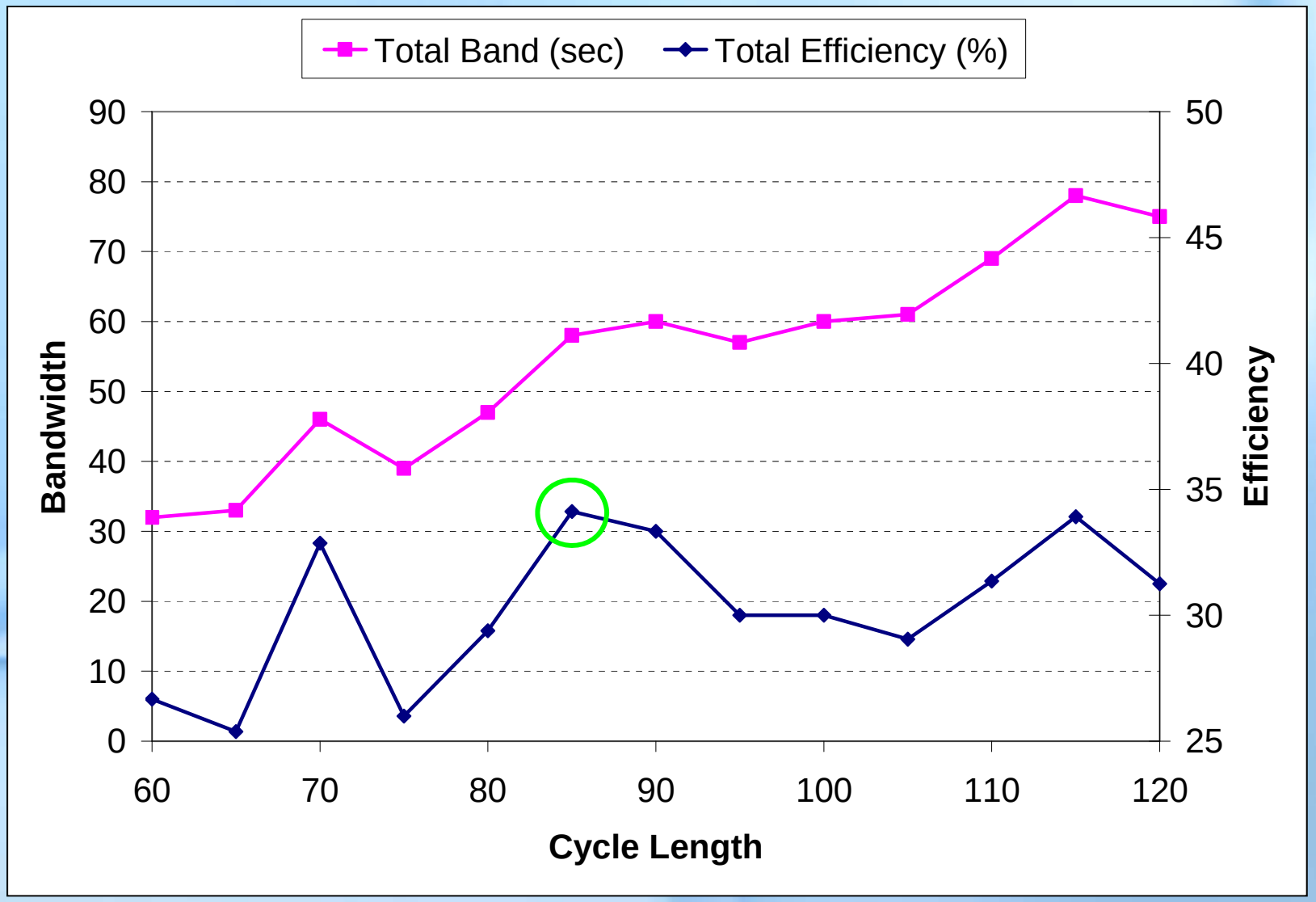
- **Handling of TWSC Intersections on Arterial**
  - ✓**Upstream Signals**
    - » Platoon Dispersion
  - ✓**Handling in Various Tools**
    - » PASSER II
    - » Other Tools (Except P3)

S5–Arterial Exercise 3

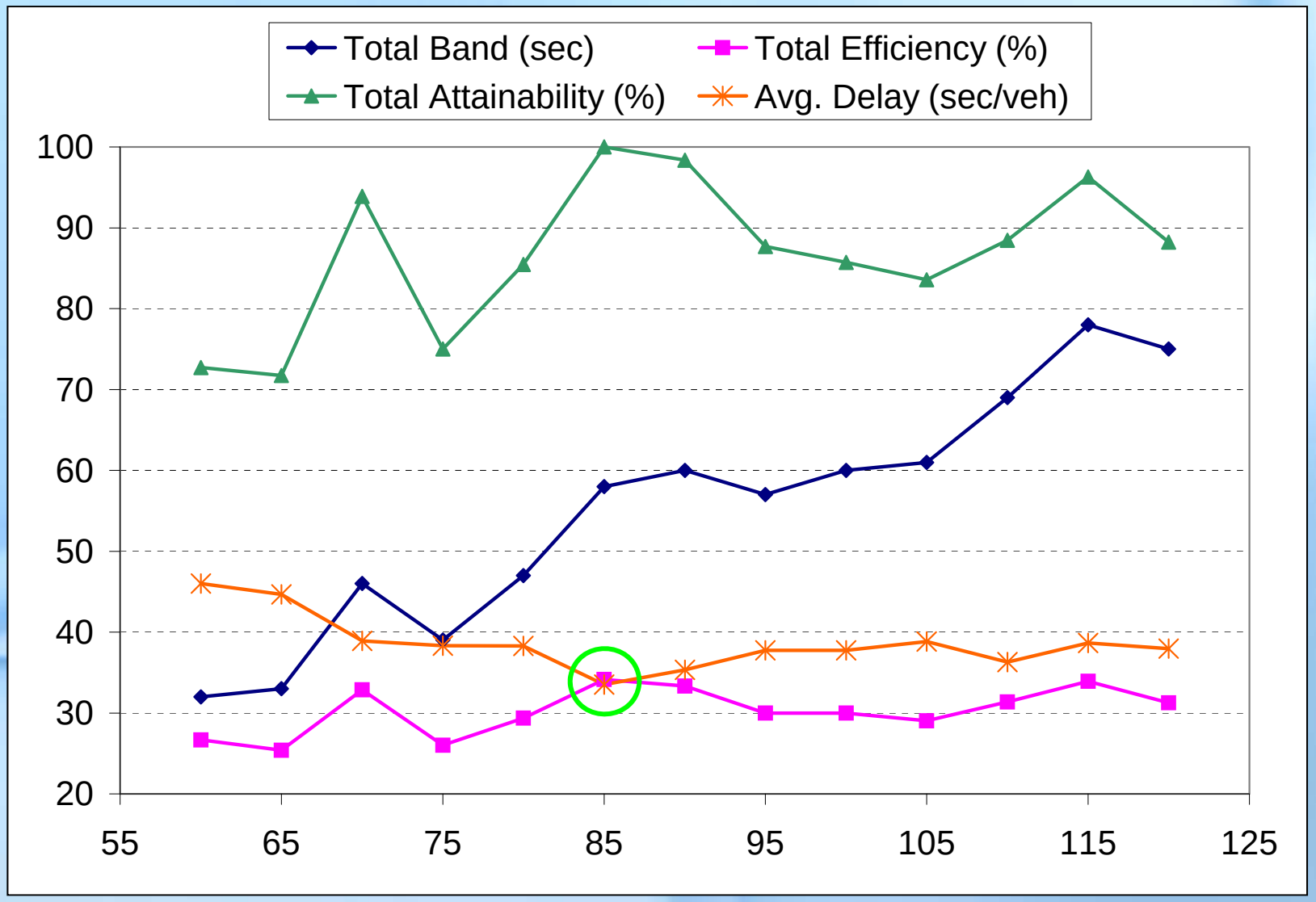
SH 71, Bastrop, Texas



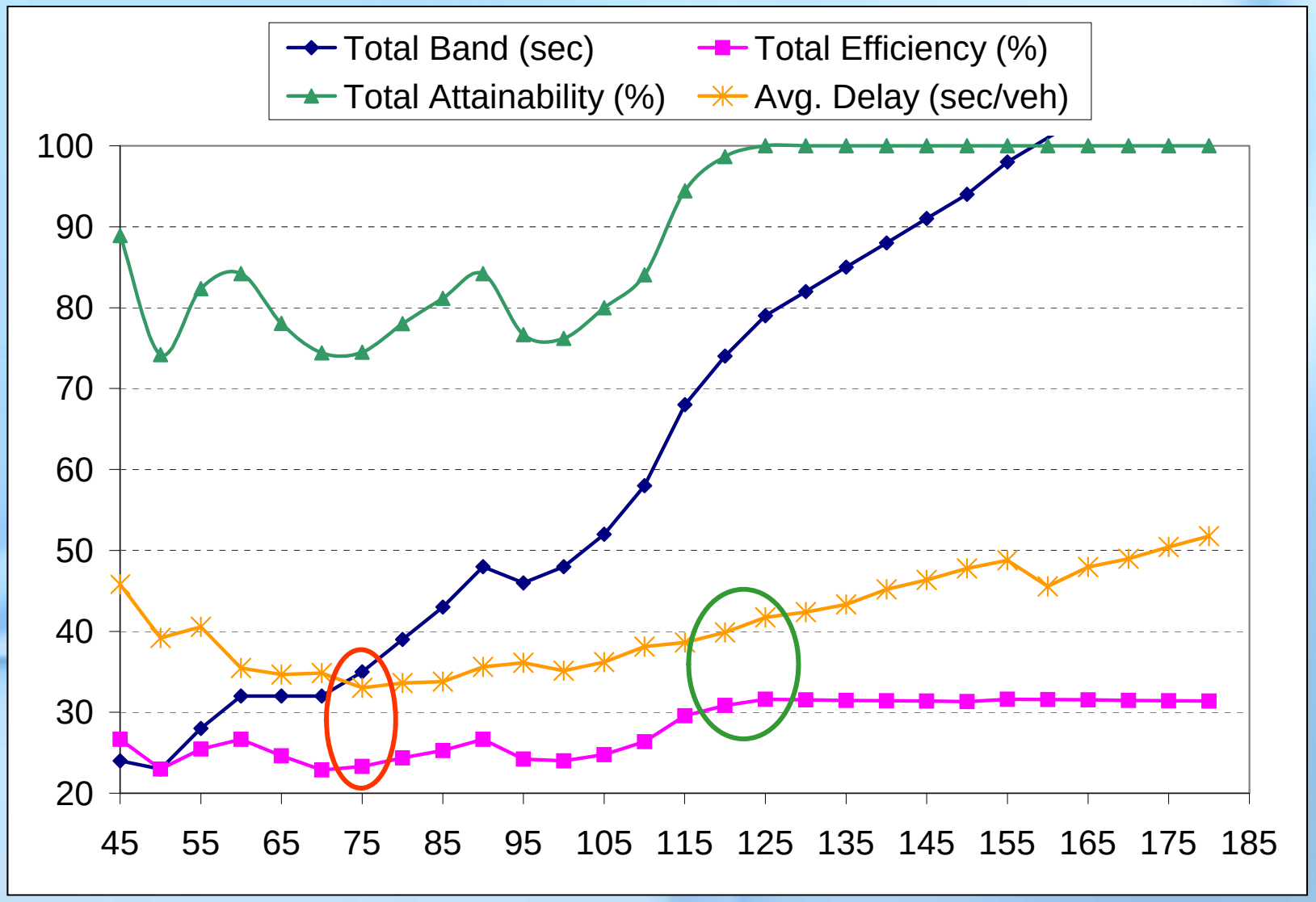
S5–Bandwidth vs. Efficiency



S5–Delay and Attainability



S5–Tradeoffs in Performance



Session 6: Diamond Interchange Analysis

- Background and Operational Issues
- Diamond Exercise
  - ✓ Create Interchange
  - ✓ Apply Optimization Tools and View Output
    - » PASSER III
    - » GA-Based Optimizer
- Apply Other Tools
  - ✓ Volume Analysis
  - ✓ Time-Space Diagram
  - ✓ Delay Analysis

S6–Background on Diamonds

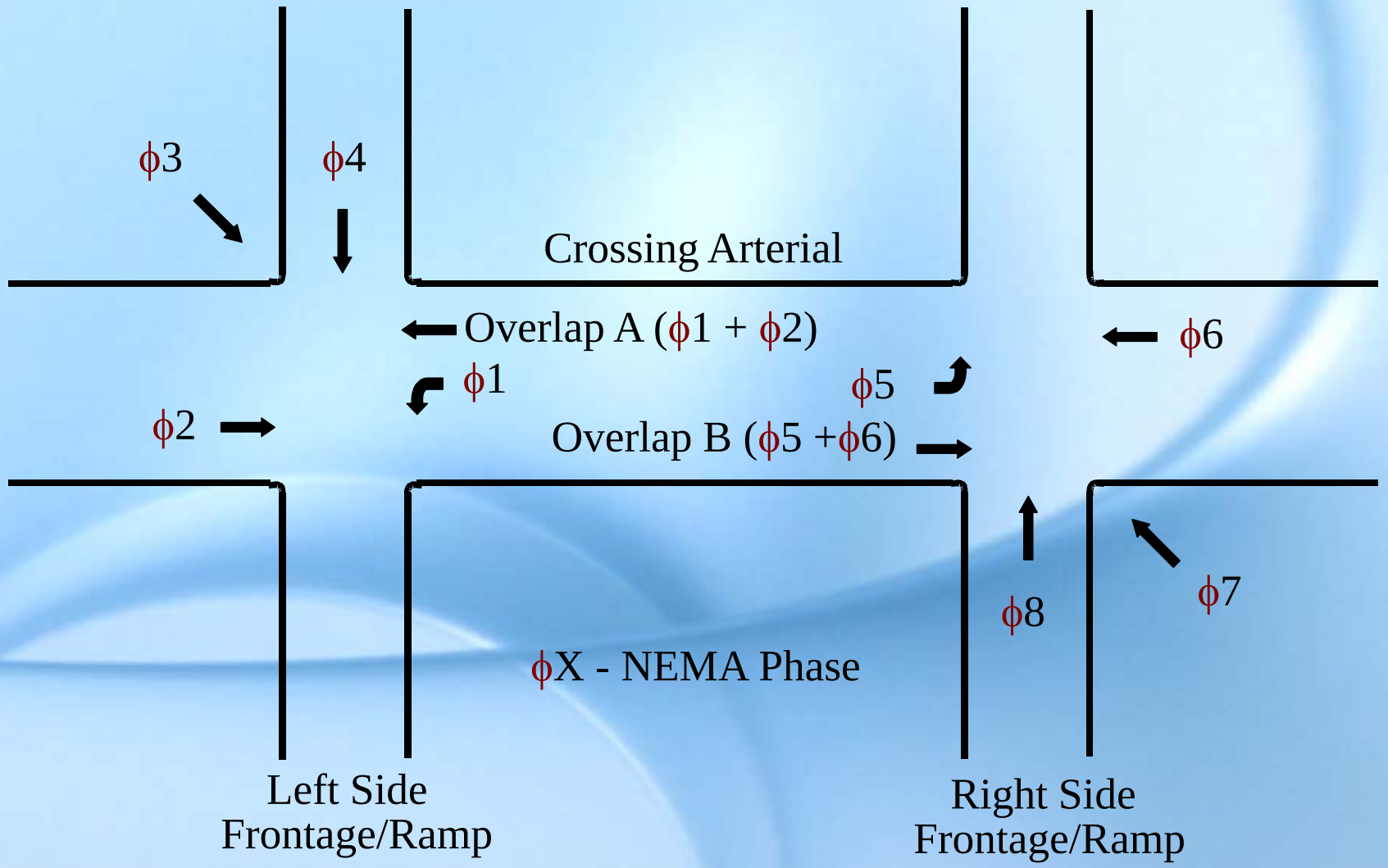
- Two Closely Spaced Intersections
- Flow Characteristics Very Different from Arterials
  - ✓Significant Turning Traffic
- Types
  - ✓Conventional (More than 800 ft)
  - ✓Compressed (400-800 ft)
  - ✓Tight (Less than 400 ft)

S6–Background on Diamonds

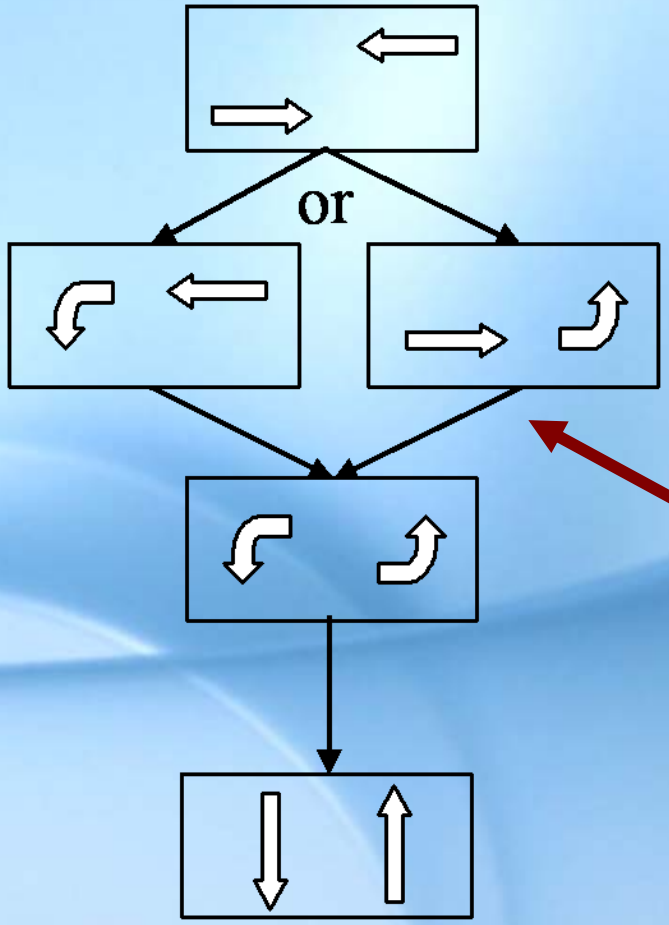
(continued)

- **Often Experience Operational Problems**
- **Capacity Dependent on**
  - ✓**Splits at Both Intersections**
  - ✓**Queuing and Spillback**
- **TxDOT/Texas Diamond Controller**
  - ✓**Basic Three-Phase**
  - ✓**TTI Four-Phase**
  - ✓**Separate Intersection Mode**

S6–NEMA Phase Numbering

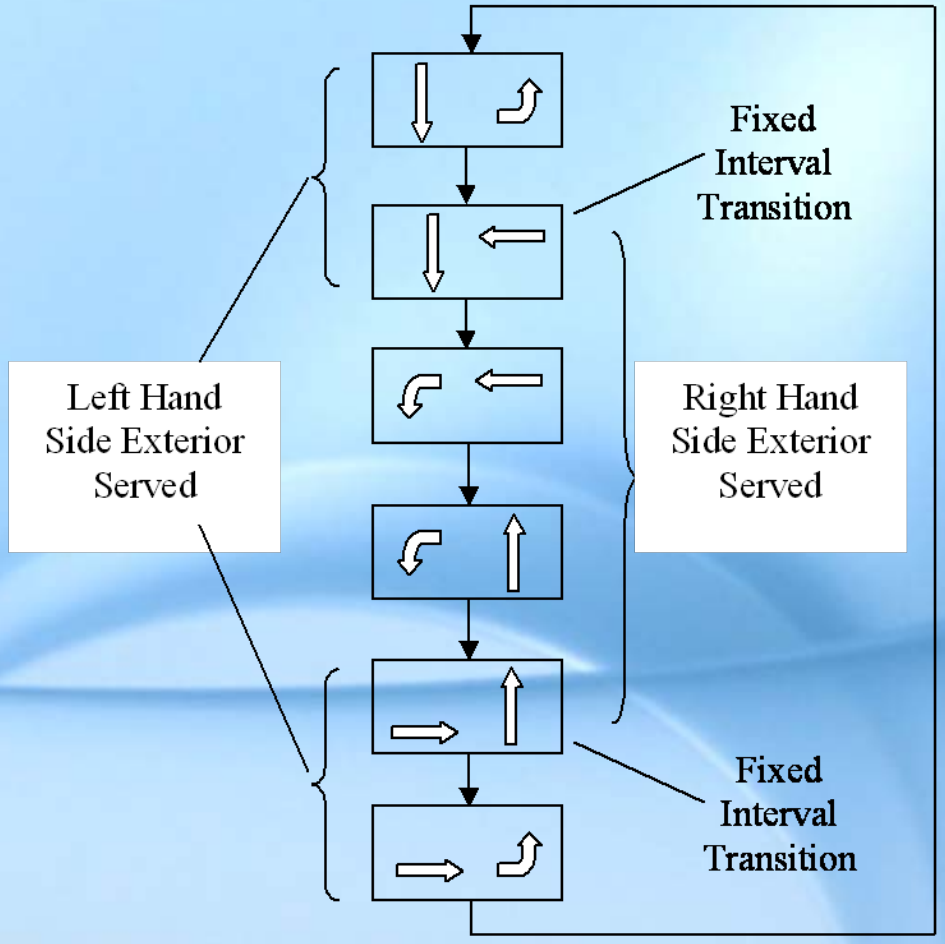


S6–Three-Phase Operation



Lag-Lag

S6–Four-Phase Operation



- Lead-Lead Phasing
- Phase Times and Offset Calculated Simultaneously
- Needs Longer Cycle

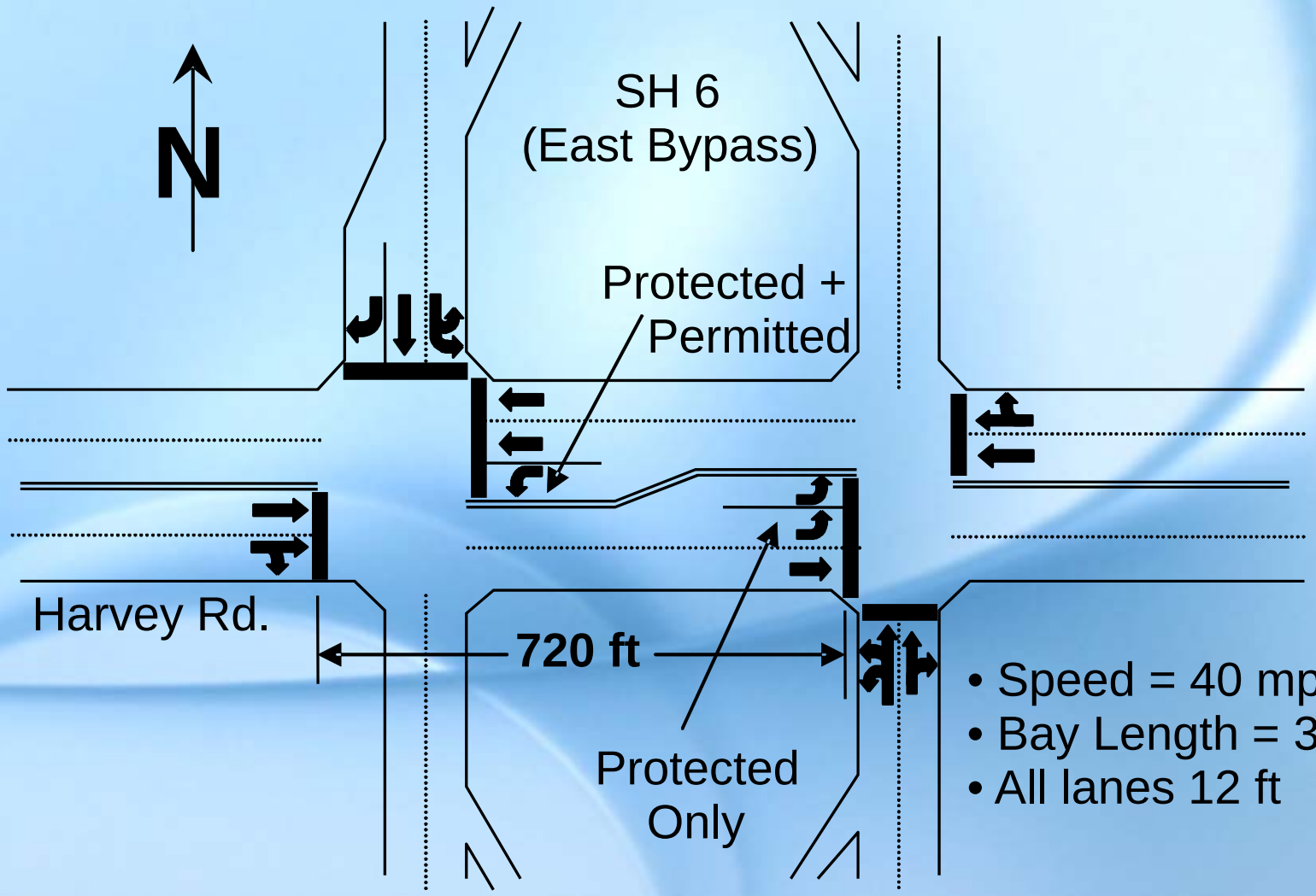
S6–Other Options

- Separate Intersection Control under Diamond Mode
  - ✓Restricted to Lead-Lead Phasing
  - ✓Can Provide Ring-lag/Offset
- User Programmed Mode
  - ✓Difficult Programming
  - ✓Flexibility of Operation
- Use Two Controllers

S6–Phasing Selection Guidelines

- **Conventional Diamonds**
  - ✓ Three-Phase
  - ✓ Four-Phase Not Recommended
- **Compressed Diamonds**
  - ✓ Three-Phase with Short Cycle
  - ✓ Four-Phase
- **Tight Diamonds**
  - ✓ Four-Phase
  - ✓ Three-Phase for Light Traffic

S6–Diamond Exercise (User Guide, p. 119)



- Speed = 40 mph
- Bay Length = 300 ft
- All lanes 12 ft

S6–Data Entry/Analysis

- Draw Links/Define Interchange
- Load Data
- Select Tool and Analyze
- Review Results

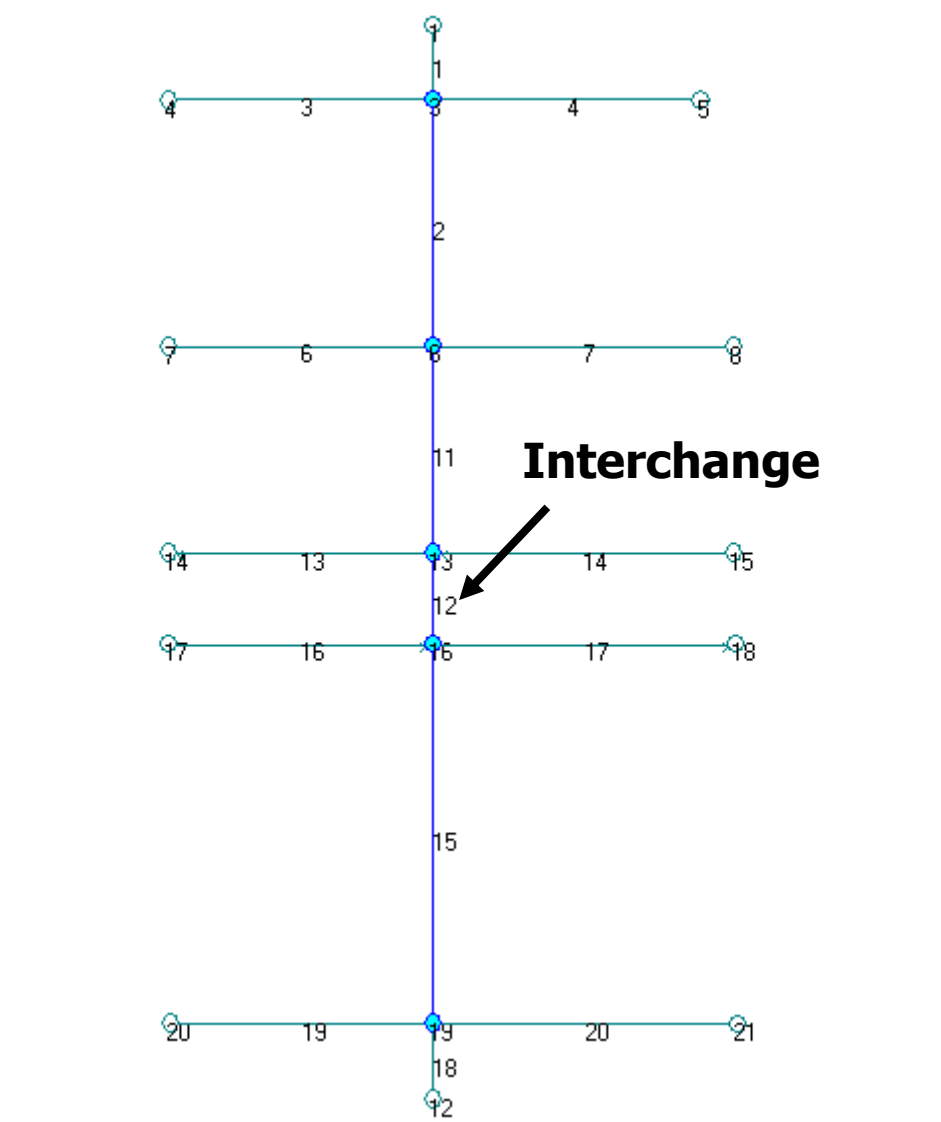
S6–More Tools in PASSER V

- Volume Analysis
- Time-Space Diagram
- Delay Analysis

Session 7: Diamond and Adjacent Signals

- Exercise Using Existing Data
- Apply Various Tools
- Review Output

S7–SH 195 Data



Session 8: Workshop Conclusion

- Additional Topics and QA Session
  - ✓Any Features Not Covered
  - ✓Networks
- Survey
  - ✓Tell Us How We Did
  - ✓Feedback about PASSER V