Signal Optimization and Analysis Using PASSER V-07
Training Workshop: Code IPR006

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

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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**

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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**

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Session 1: Introduction to PASSER V

- **Background**
- **Features**
- **Input Data Requirements**
- **User Interface**

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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**

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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**

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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**
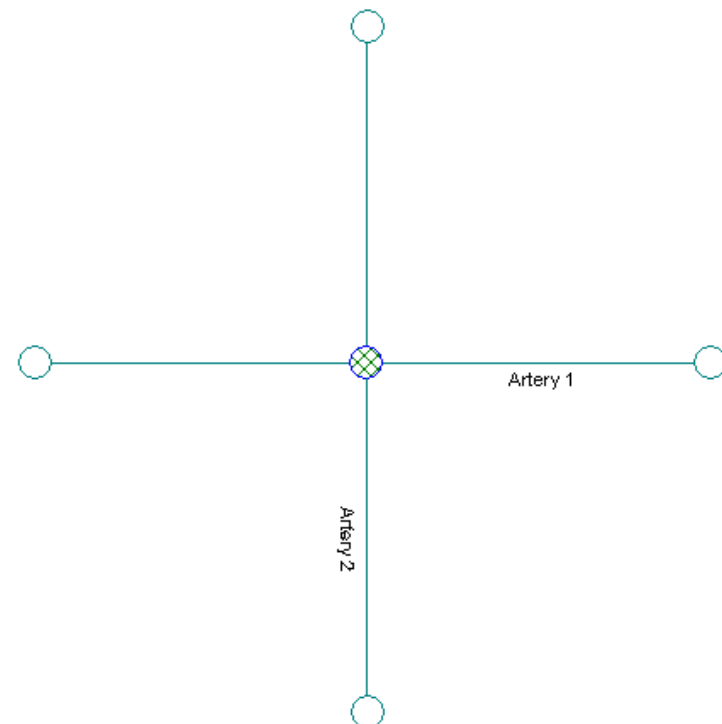
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S2–Exercise

S2-Exercise (User Guide, p. 91)

N

S.W. Military

S. Presa

Bay is 91' long

	AM	PM
L	13	**19**
T	52	**68**
R	74	**150**
Truck%	2	**1**

	AM	PM
L	24	**44**
T	386	**635**
R	16	**21**
Truck%	3	**1**

Bay is 148' long

Bay is 153' long

	AM	PM
L	88	**149**
T	397	**676**
R	86	**147**
Truck%	3	**1**

	AM	PM
L	113	**113**
T	85	**80**
R	45	**49**
Truck%	8	**1**

Bay is 126' long

13' 13'   13'

14'   11'   12'

10'   12'   11'   12'   13'

11'

11' 14'

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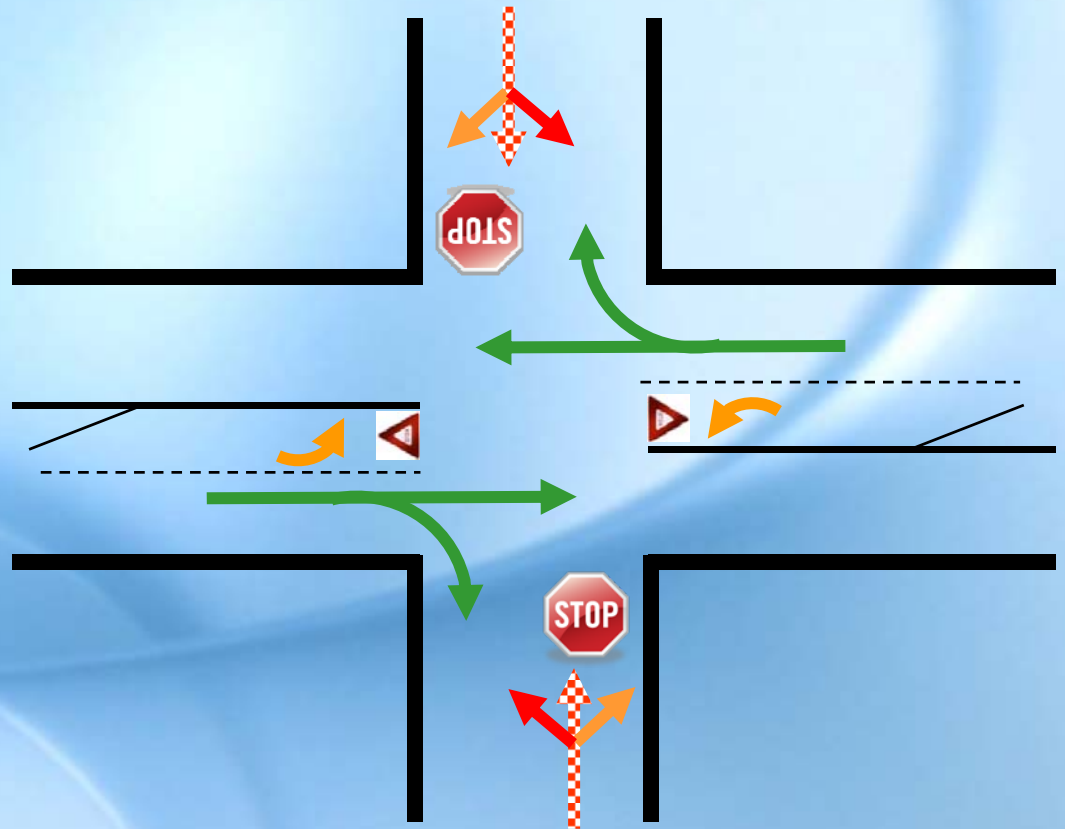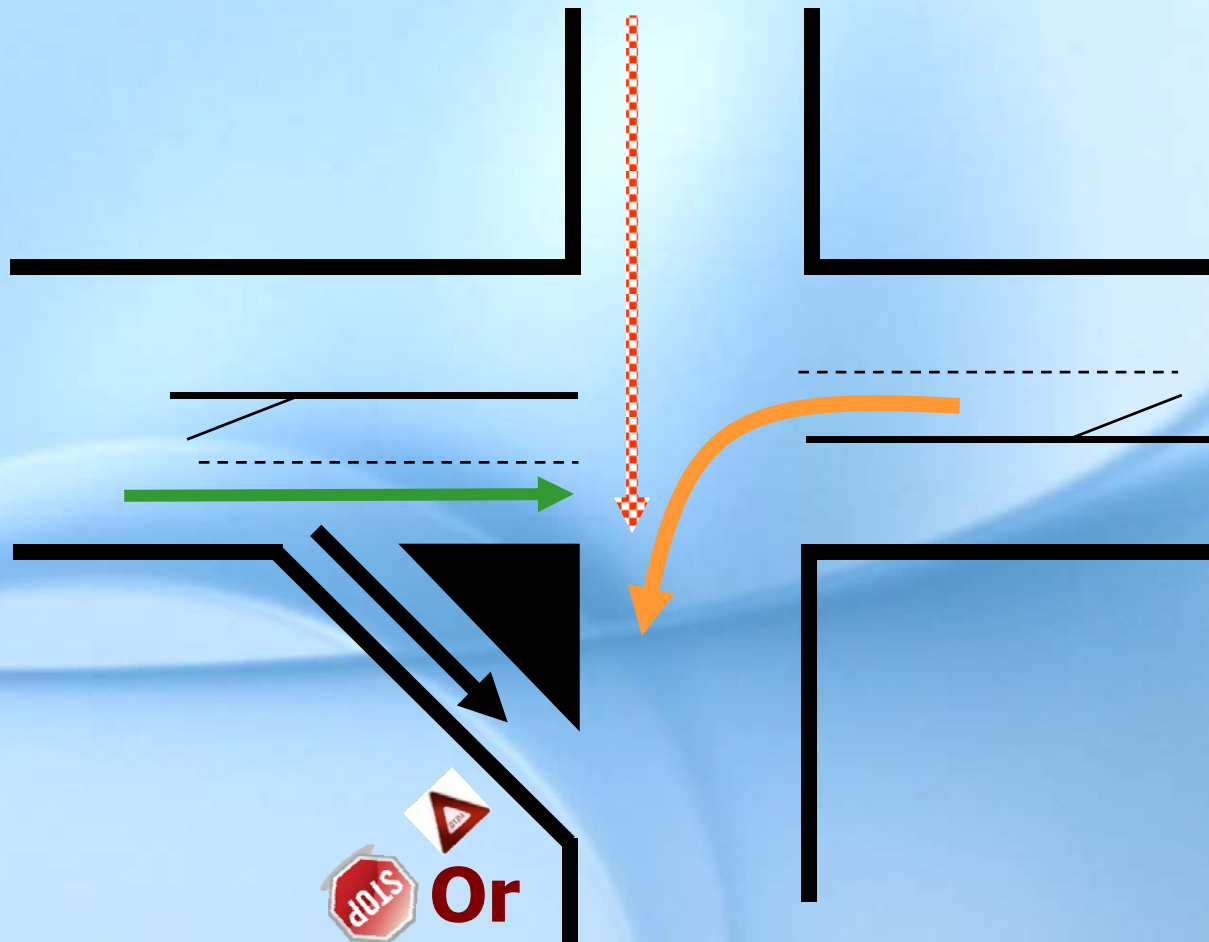
S2−Gap Acceptance

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

S2–Channelized Rights

Or

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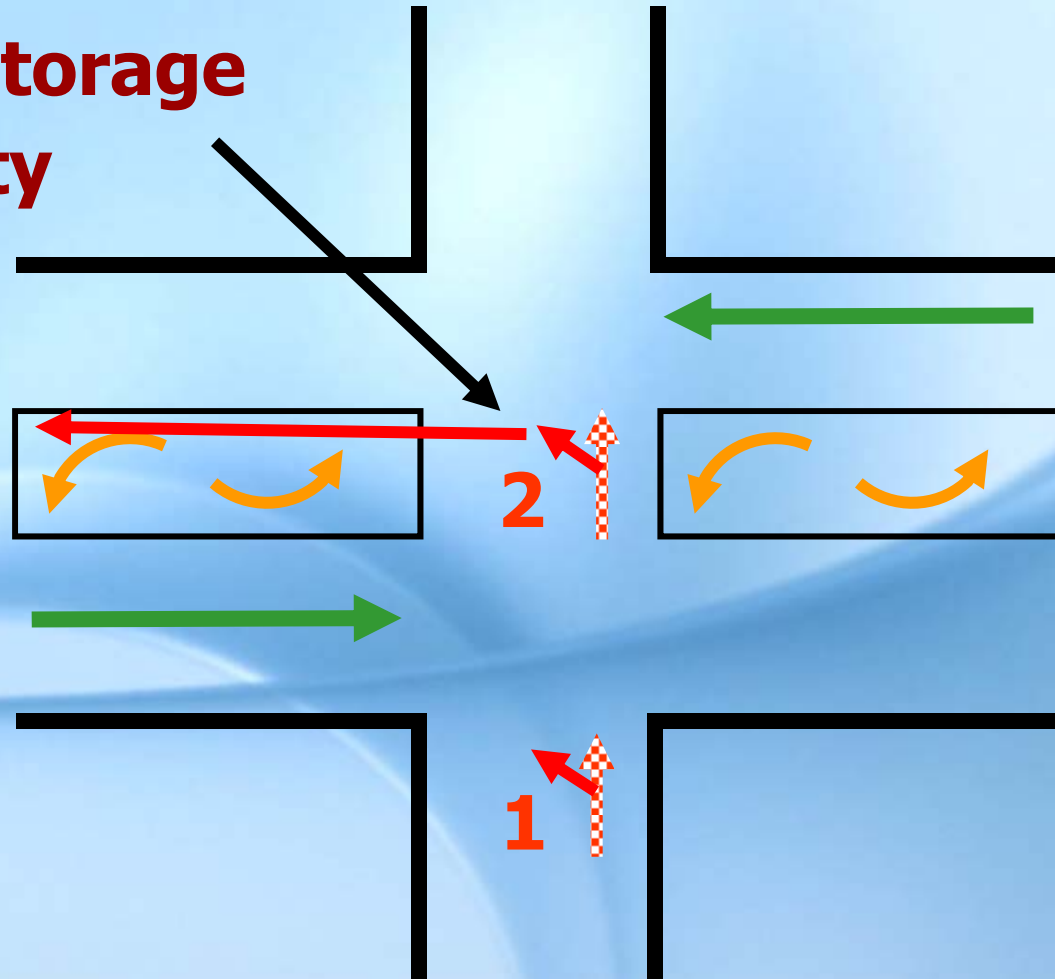Transportation
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S2 – Two-Stage Process

Enter Storage Capacity

2

1

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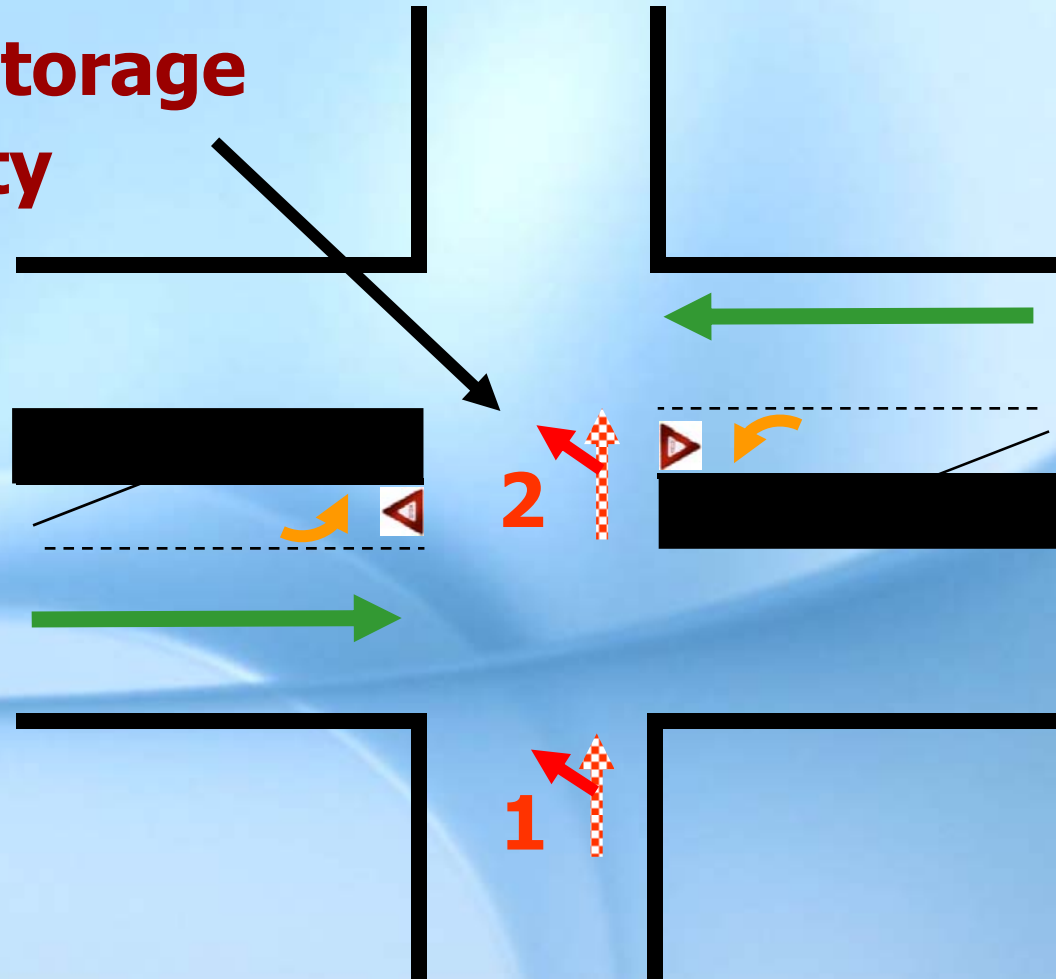
S2 – Two-Stage Process *(continued)*

Enter Storage Capacity

S2–Flared Approaches

Specify How Many

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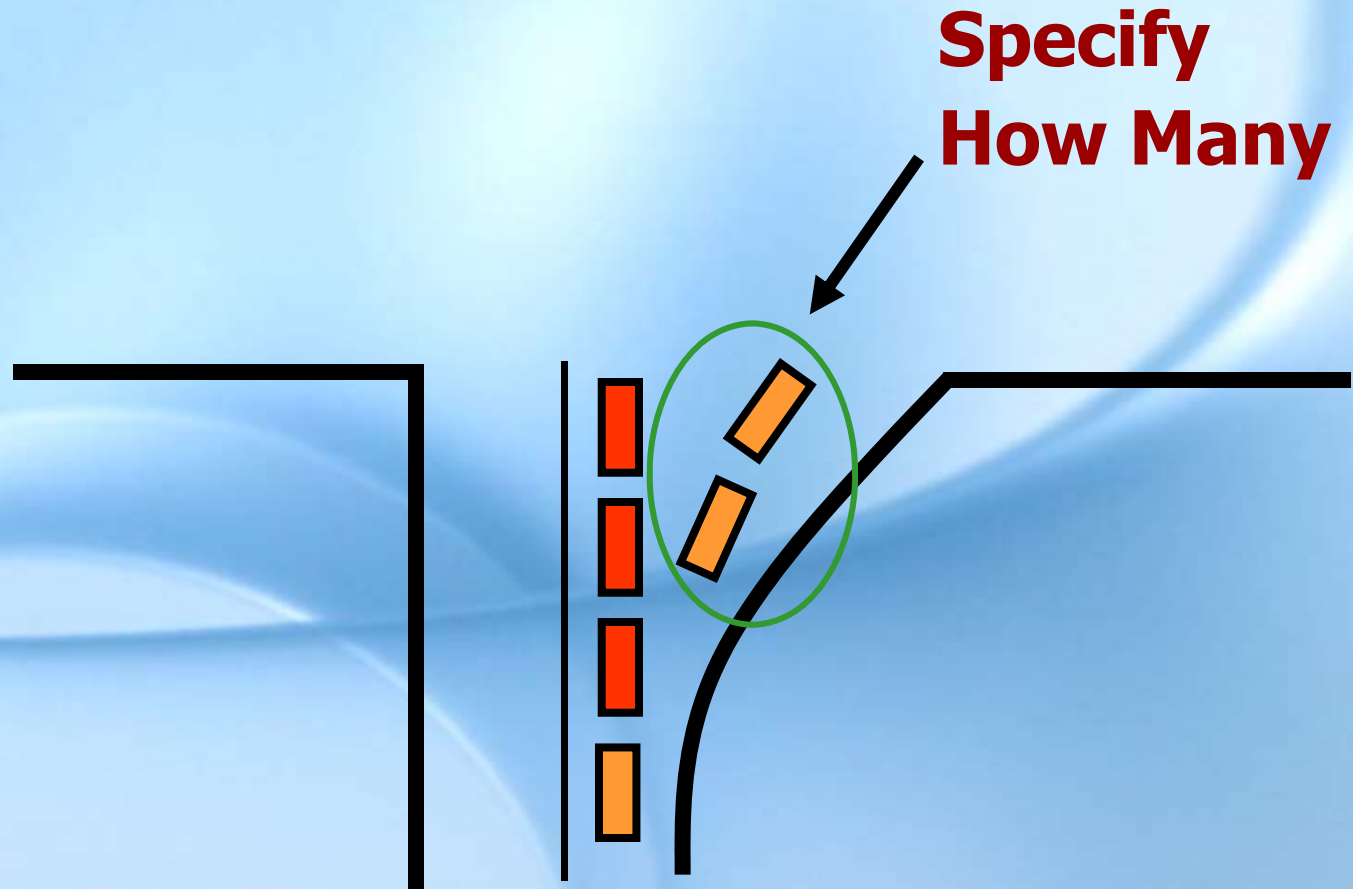
S2–Model Parameters

- **Critical Headway**
- **Follow-up Time**

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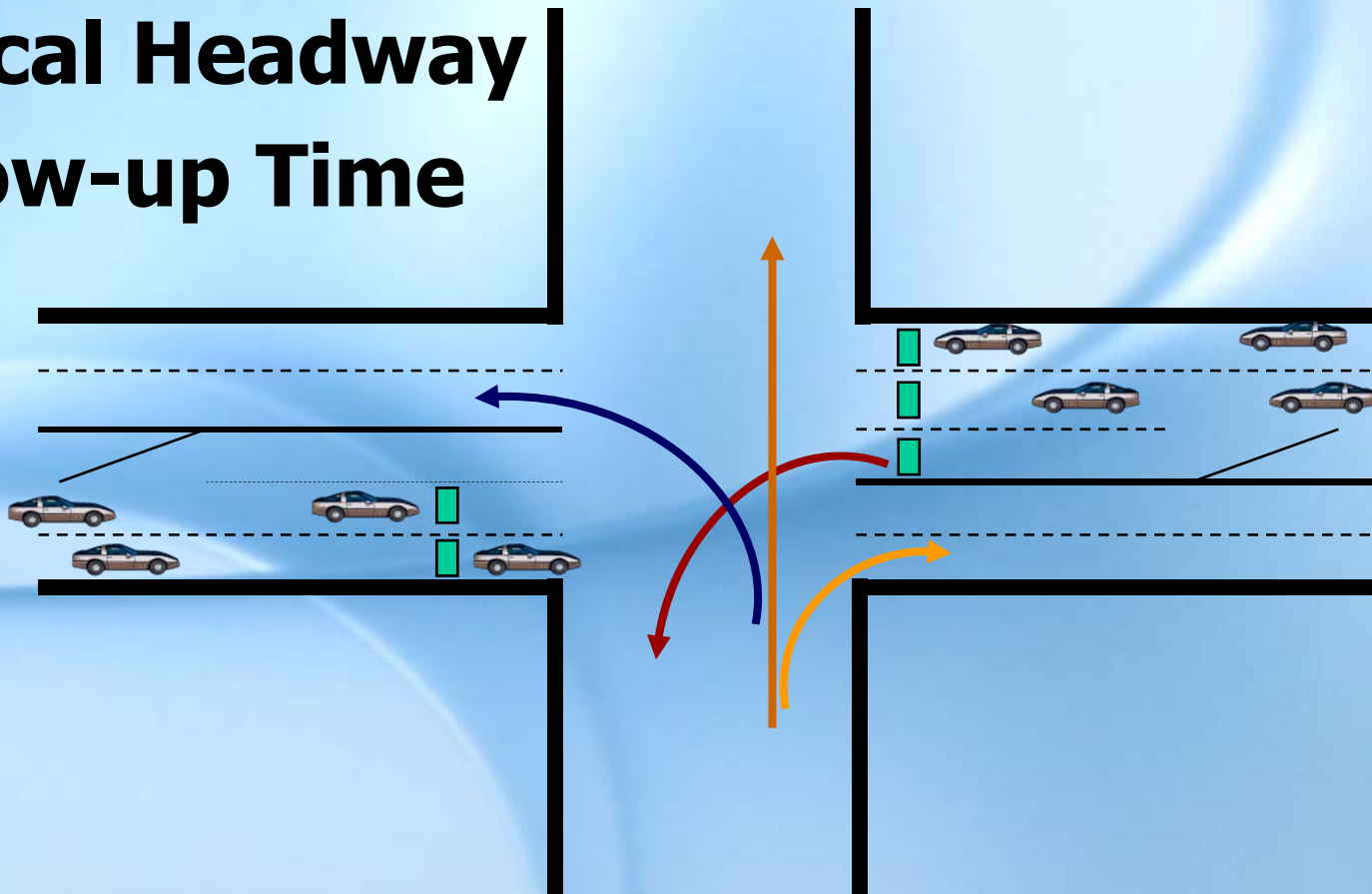
Session 3: Isolated Signals

- **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**

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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**

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S3−Performance Data

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

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S3-NEMA Phase Numbering
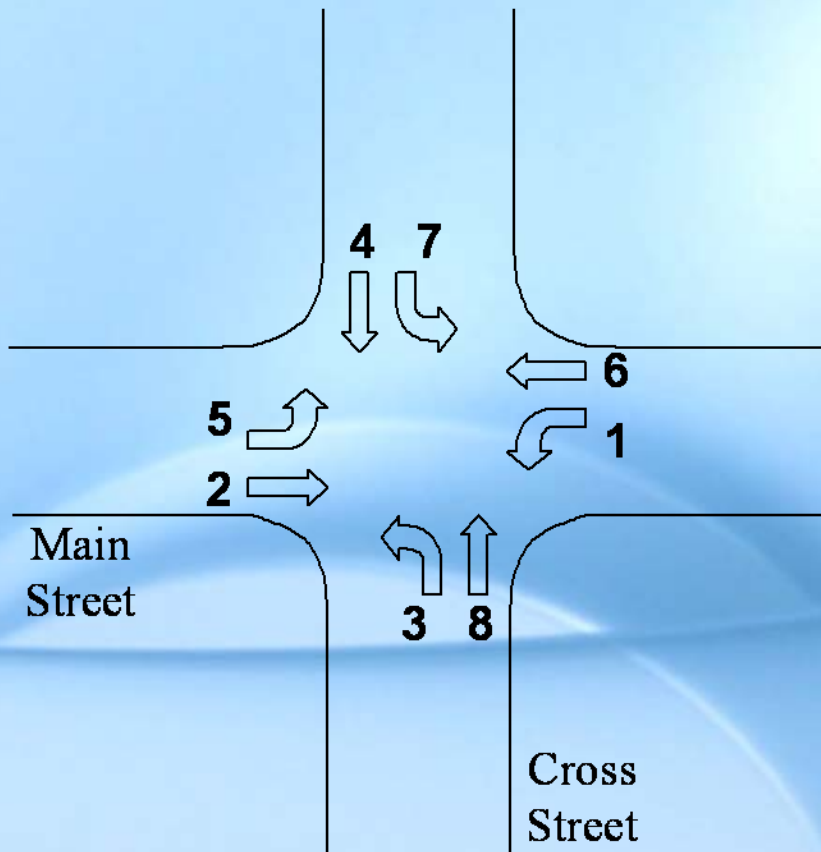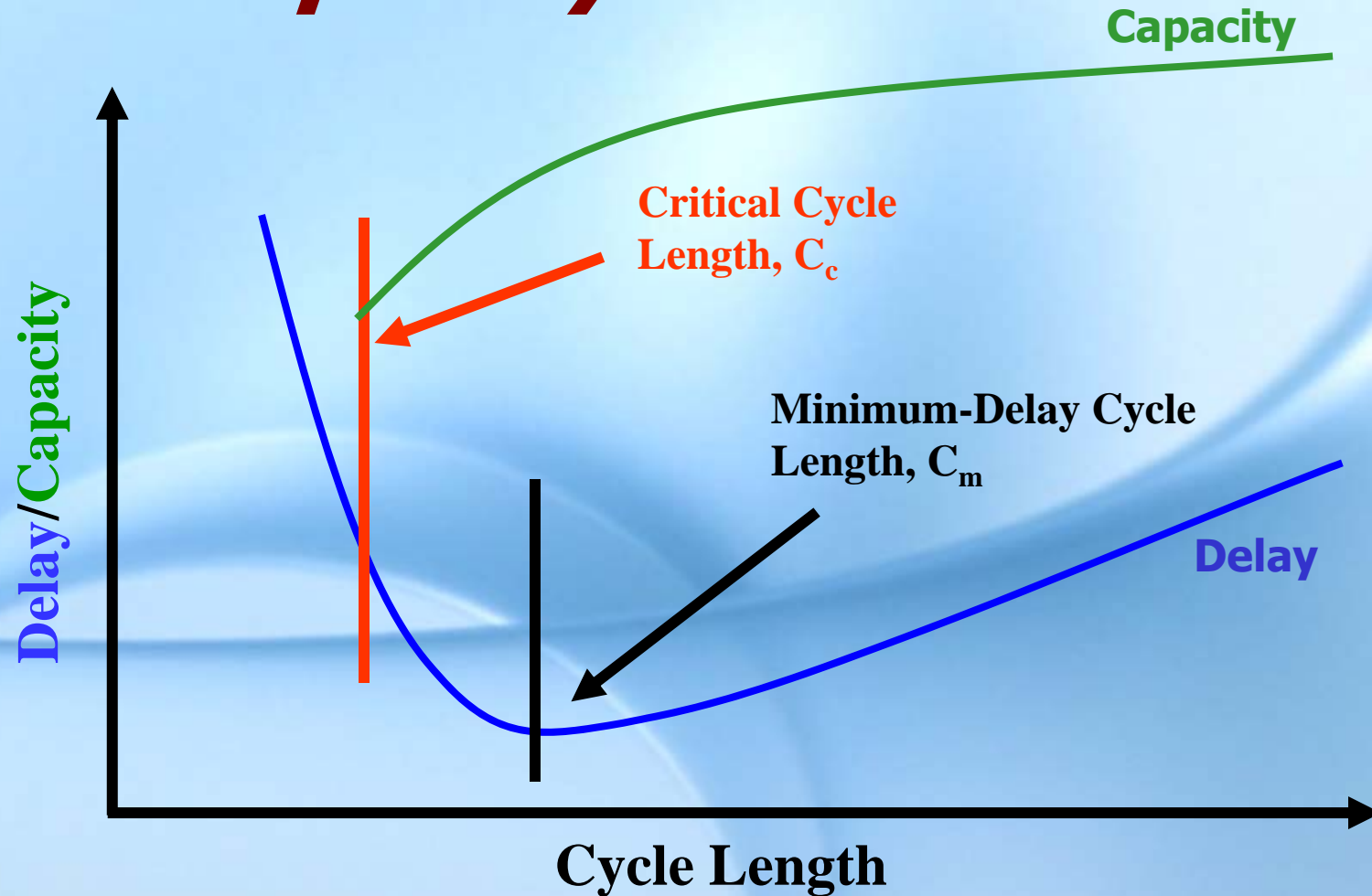

NEMA Dual-Ring Phasing
(leading lefts, no overlap)

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

S3−Cycle Length vs. Delay and Capacity

Capacity

Critical Cycle Length, C_c

Minimum-Delay Cycle Length, C_m

Delay

Delay/Capacity

Cycle Length

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S3—Cycle Length vs. Delay and Stops

Queue

Queue

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S3–Cycle Length vs. Delay

Queue

Delay Comparison

Queue

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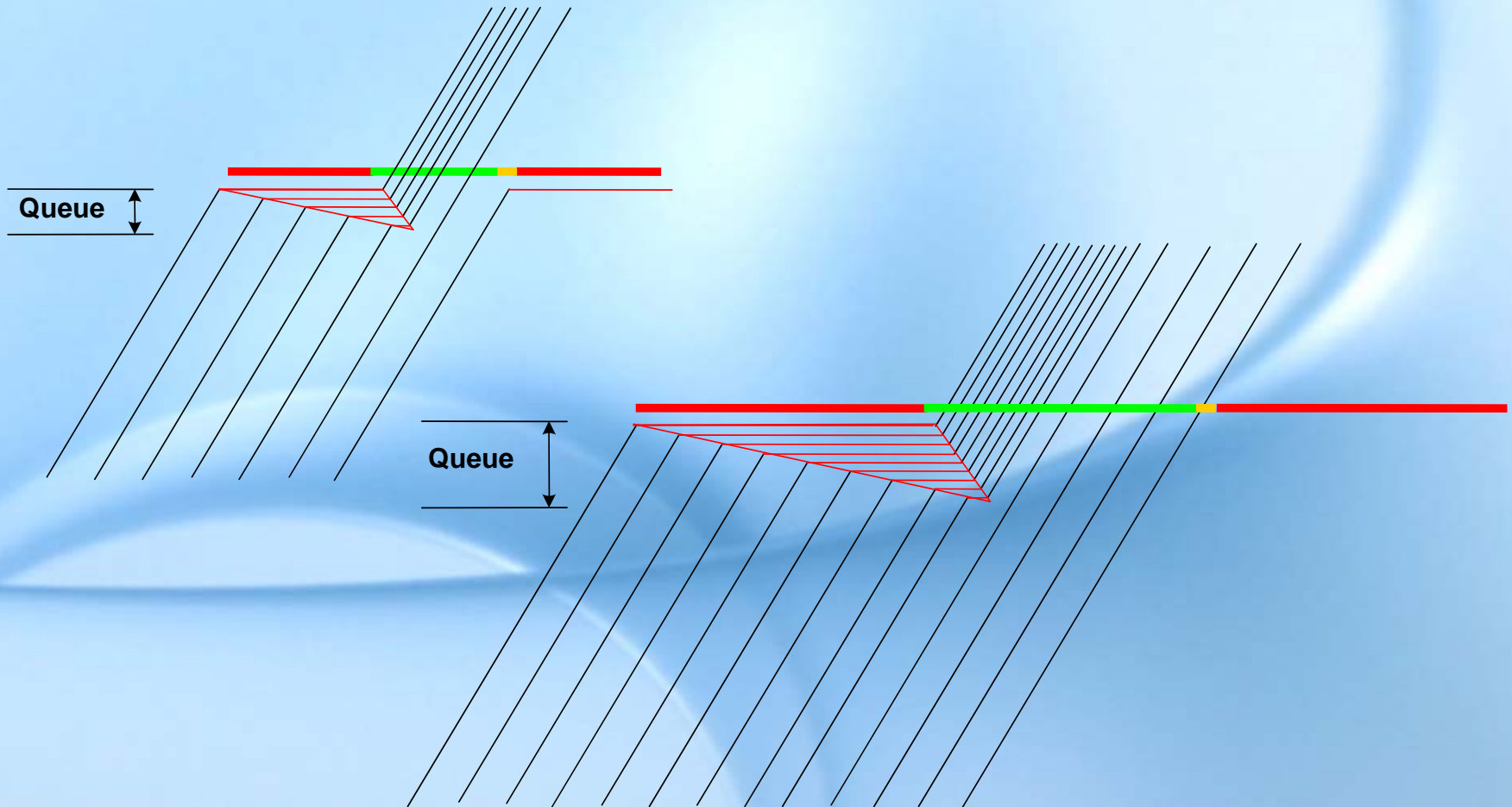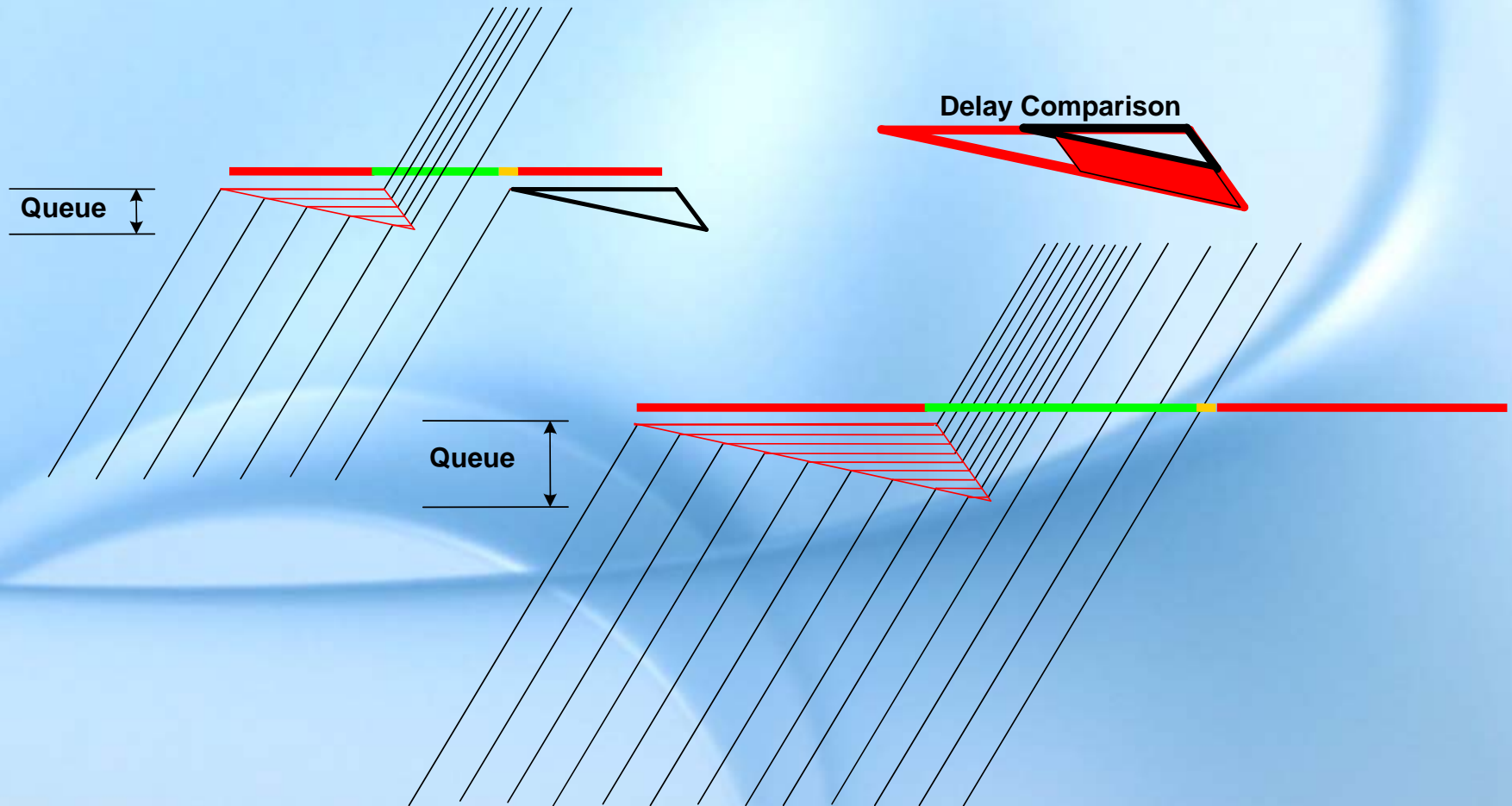
S3-Timing Isolated Signals

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

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S3 – Safety Issues

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

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S3–Clearance Intervals

- ## Proper Settings Avoid a "Dilemma Zone"

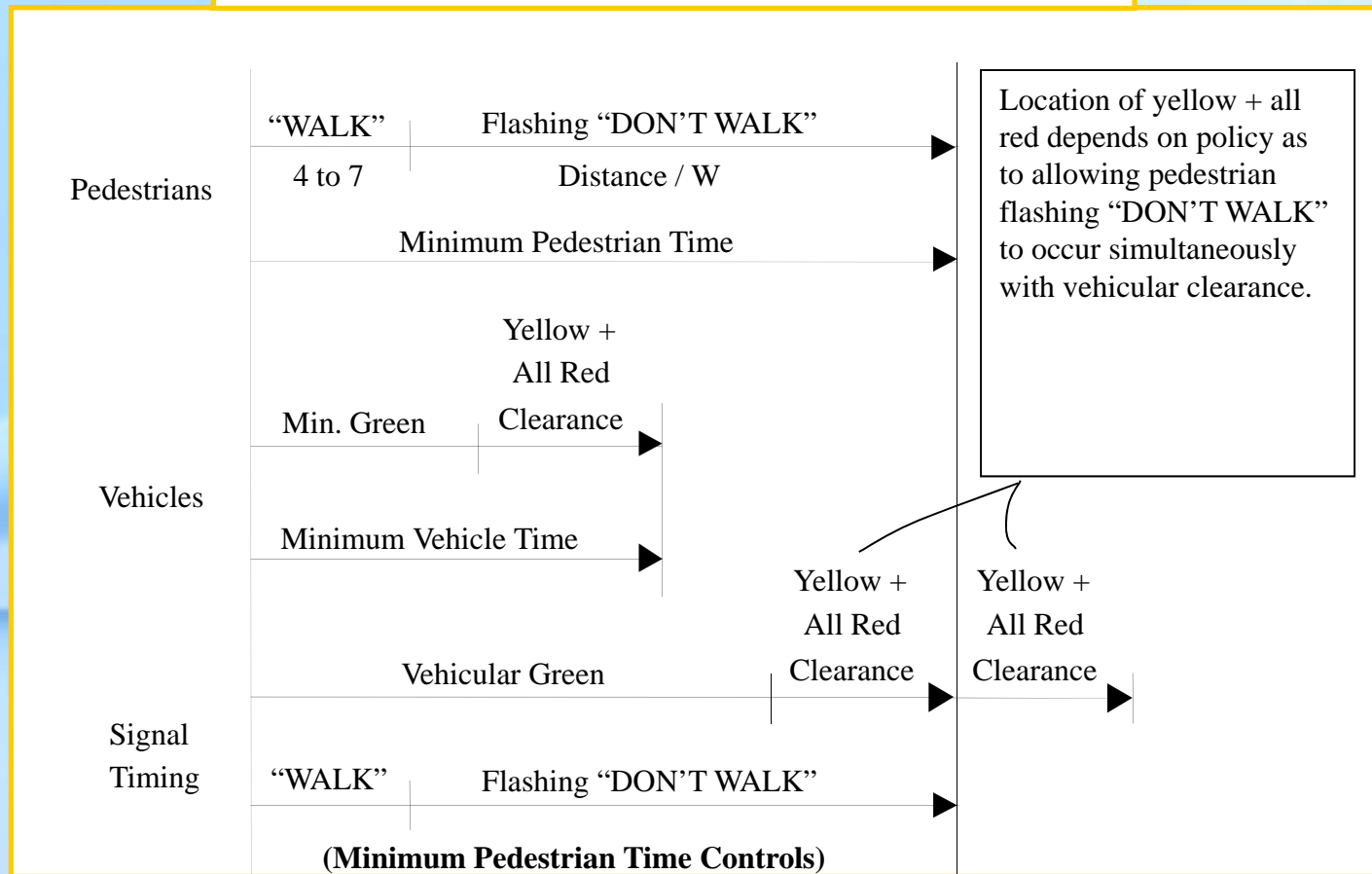| Speed mph	Yellow Change sec (level grade)		Red Clearance sec (60' wide crossing)
25	2.84		2.18
35	3.57		1.55
45	4.31		1.21
55	5.04		0.99
65	5.78		0.84

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S3–Pedestrians

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

Pedestrians

"WALK" | Flashing "DON'T WALK"

4 to 7 | Distance / W

Minimum Pedestrian Time

Vehicles

Yellow + All Red Clearance

Min. Green

Minimum Vehicle Time

Signal Timing

Vehicular Green

Yellow + All Red Clearance

Yellow + All Red Clearance

"WALK" | Flashing "DON'T WALK"

(Minimum Pedestrian Time Controls)

Location of yellow + all red depends on policy as to allowing pedestrian flashing "DON'T WALK" to occur simultaneously with vehicular clearance.

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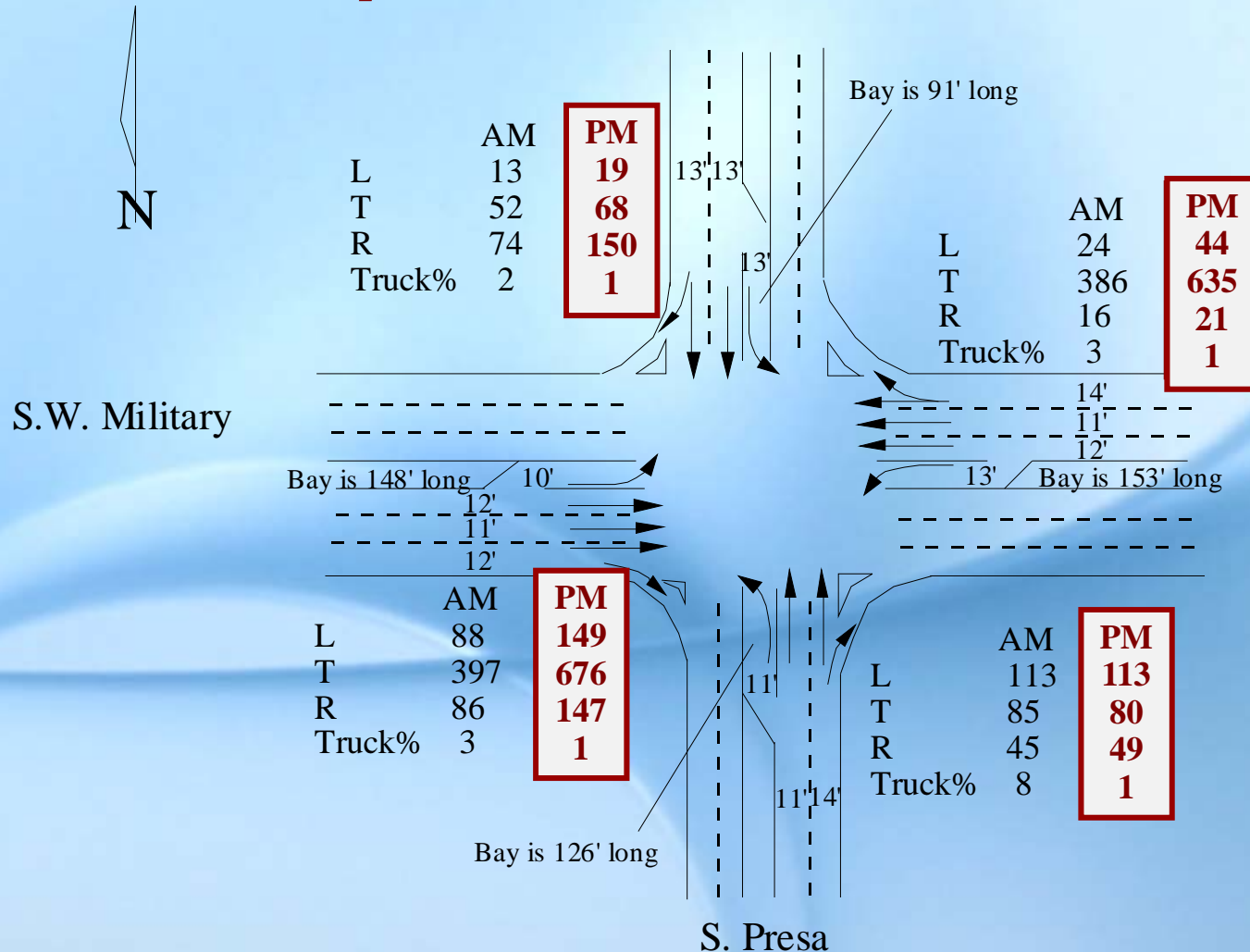
S3 – Best Isolated Operation

- **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**

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S3–Intersection Data (User Guide, p. 91)
S.W. Military at S. Presa, San Antonio, Texas

N

Bay is 91' long

	AM	**PM**
L	13	**19**
T	52	**68**
R	74	**150**
Truck%	2	**1**

13' 13'

13'

	AM	**PM**
L	24	**44**
T	386	**635**
R	16	**21**
Truck%	3	**1**

S.W. Military

14'
11'
12'

Bay is 148' long   10'
12'
11'
12'

13'   Bay is 153' long

	AM	**PM**
L	88	**149**
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11'

	AM	**PM**
L	113	**113**
T	85	**80**
R	45	**49**
Truck%	8	**1**

11' 14'

Bay is 126' long

S. Presa

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**

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S3–Analysis/Results

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

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Session 4: Signal Systems

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

S4–Flow Stability between Adjacent Systems

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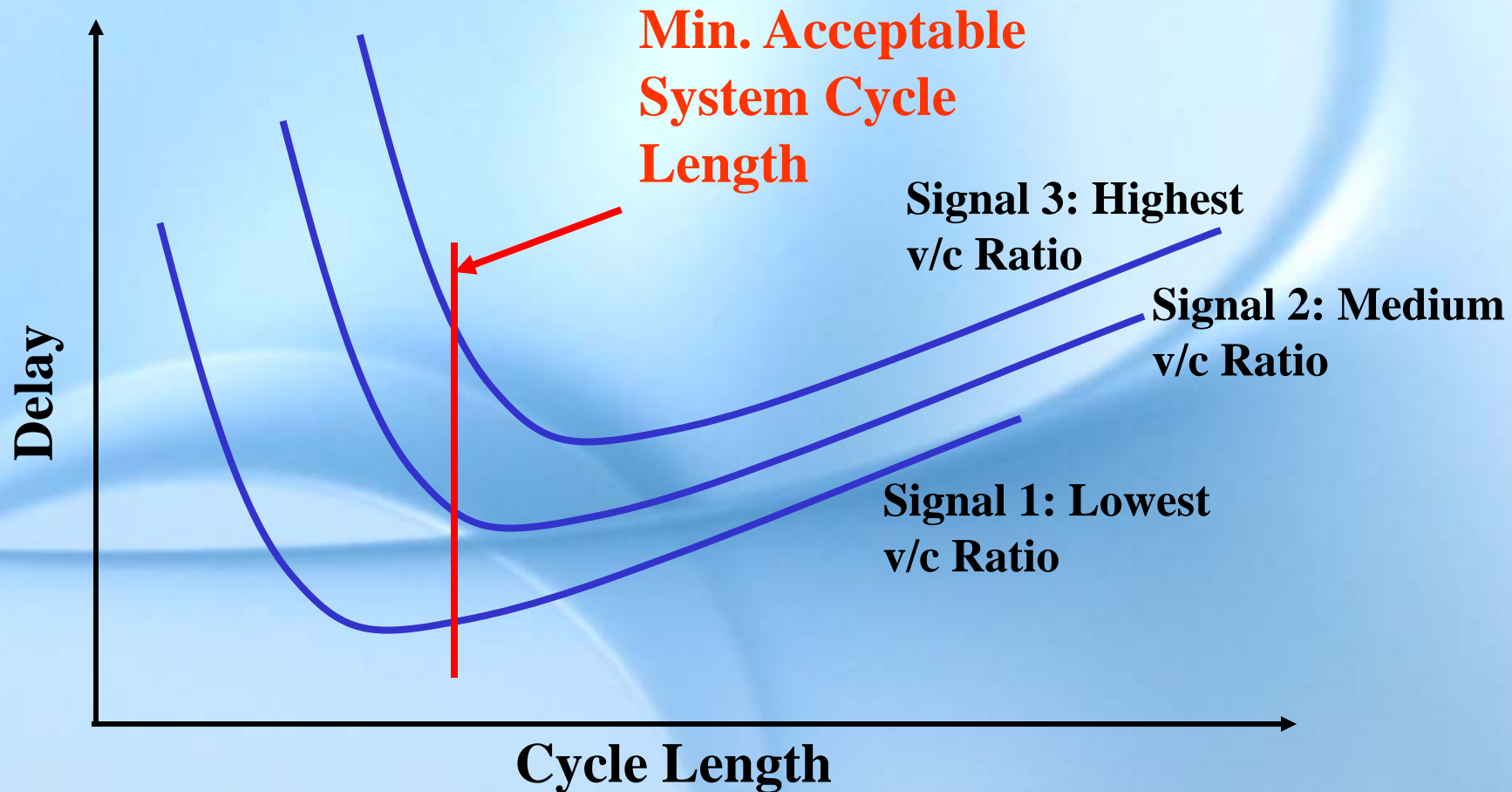
S4–Signal Offset and Flow between Adjacent Signals

Offset

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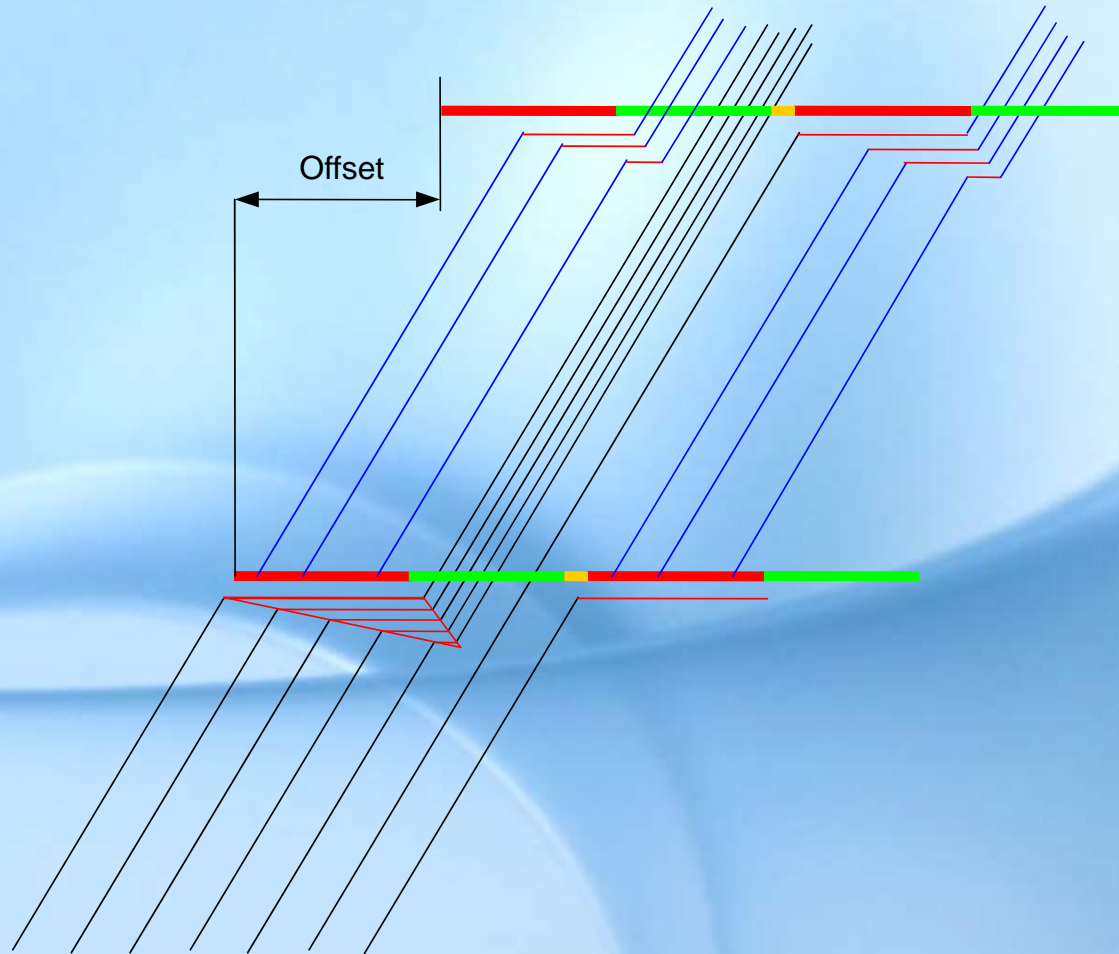
S4–Flow vs. Bands
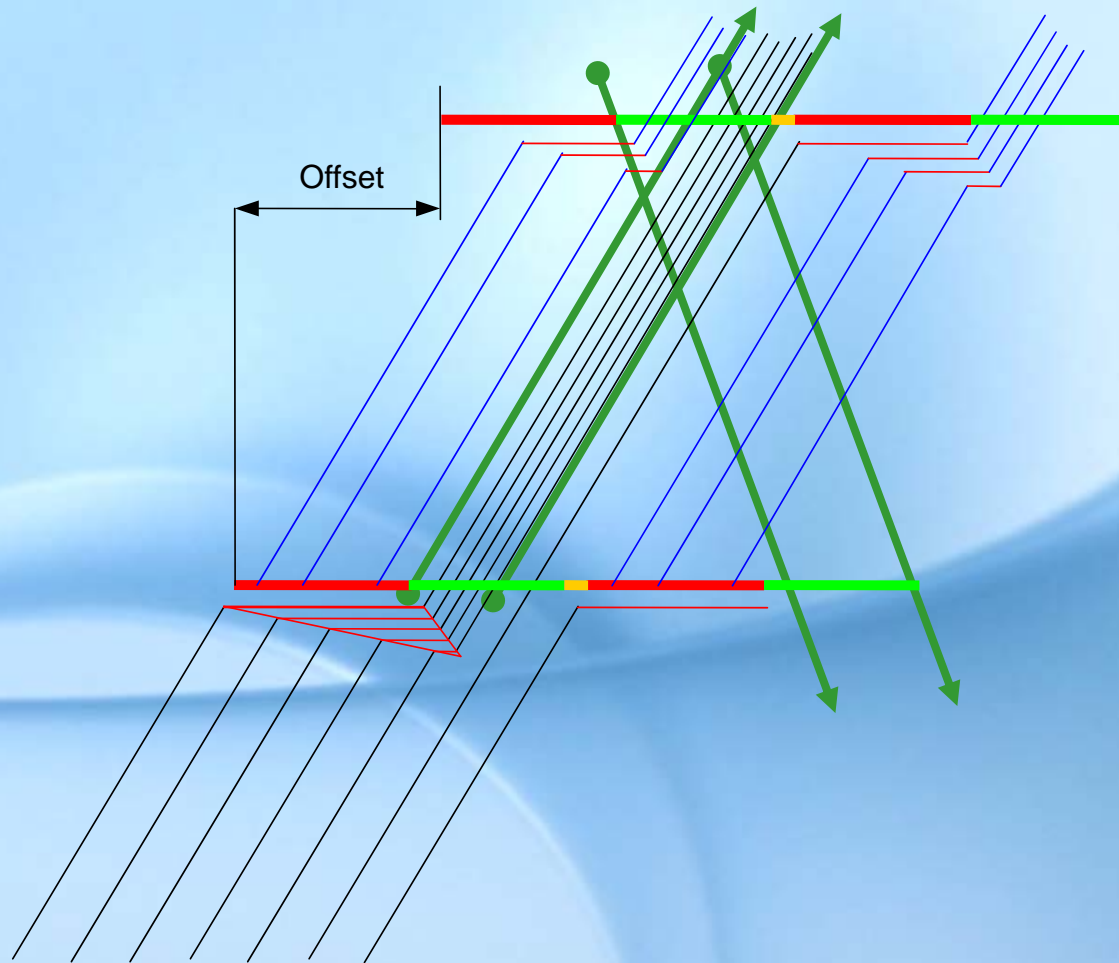
Offset

S4–Effects of Changes in Offset

Offset +

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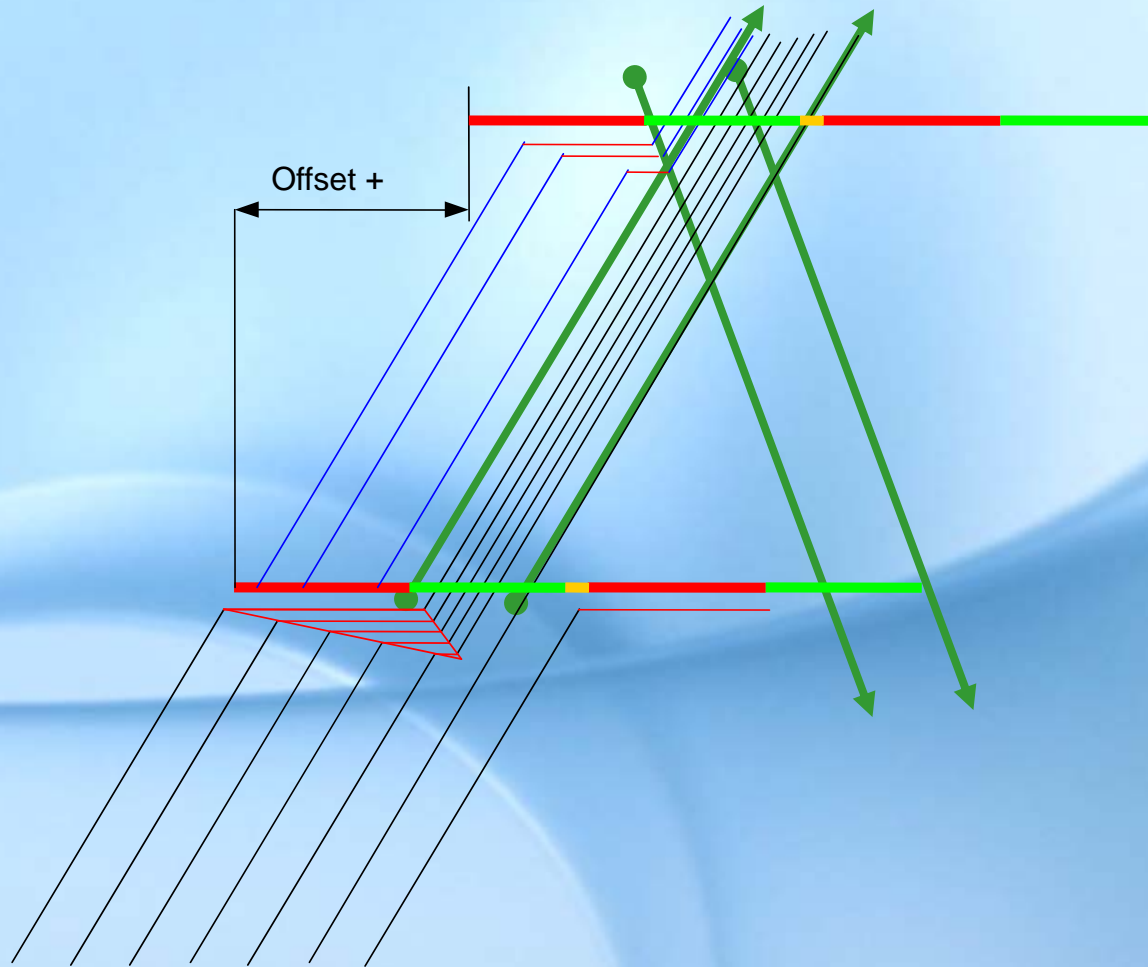
S4−Cannot Get Two-way Bands? Change Phasing!

Offset -

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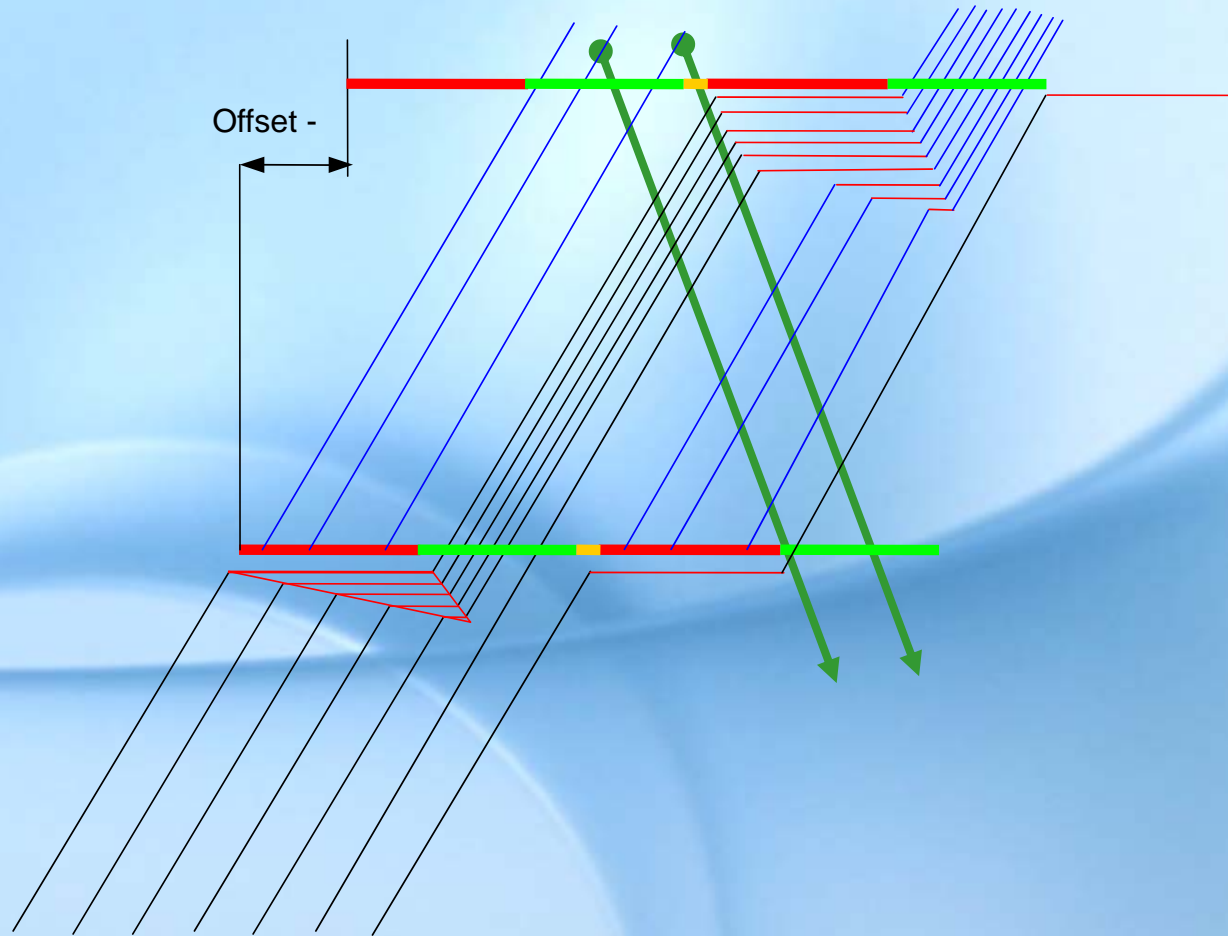
S4–Changing Phasing Can Improve 2-way Progression

Offset -

S4–Yellow Trap

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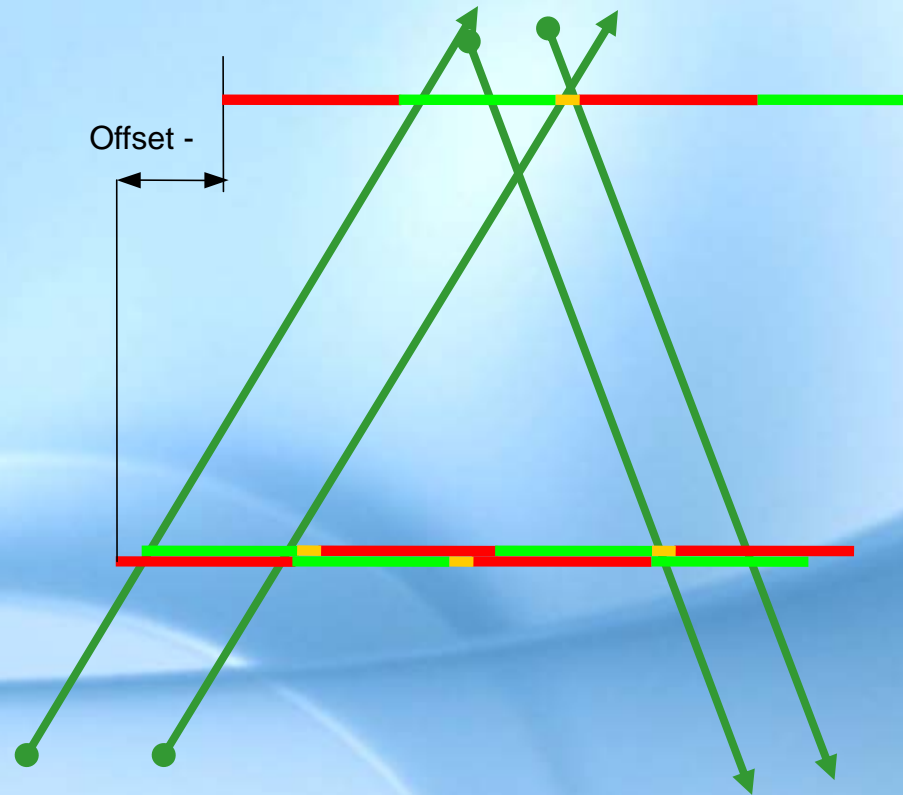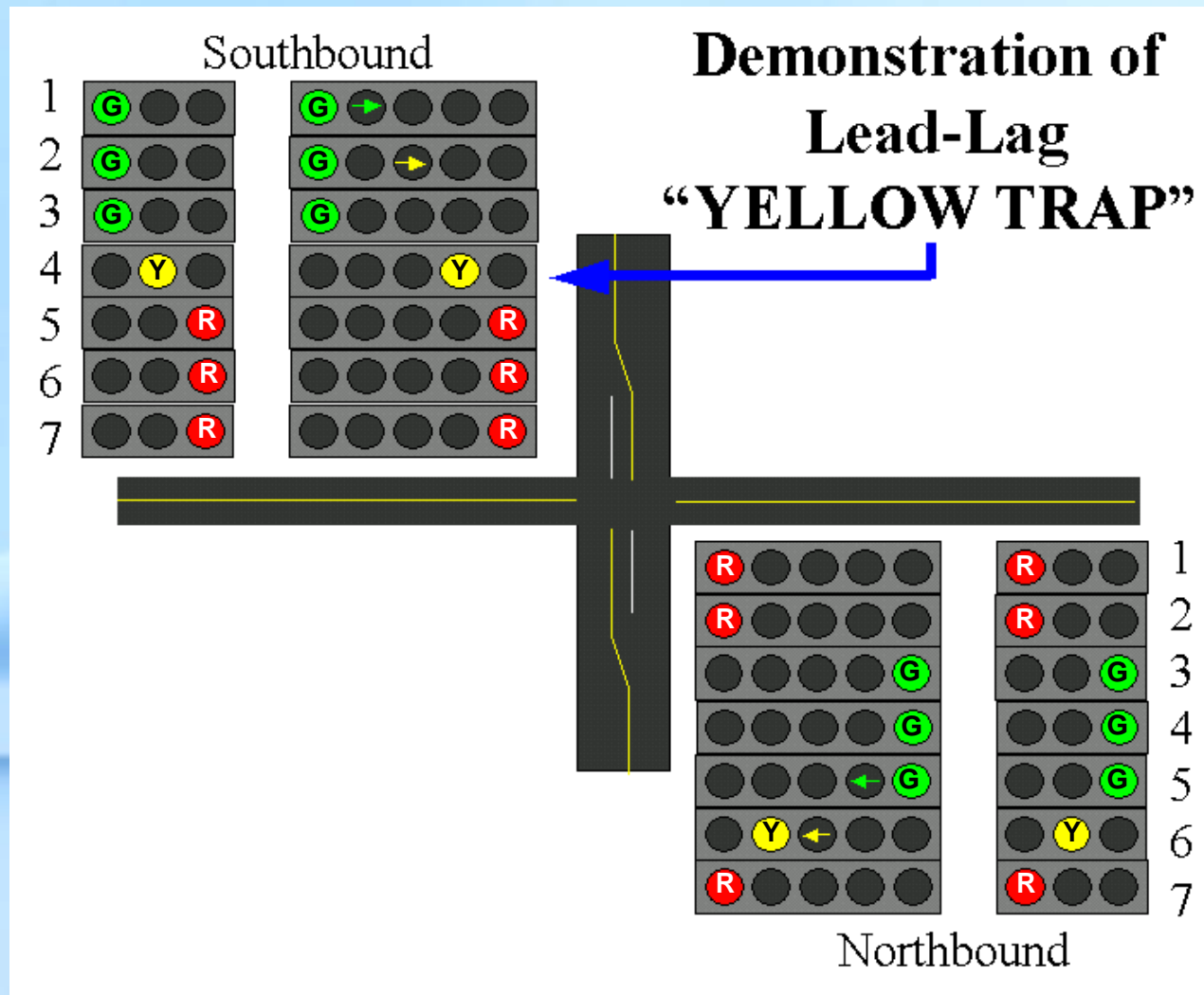
S4−Yellow Trap *(continued)*

Arlington Phasing
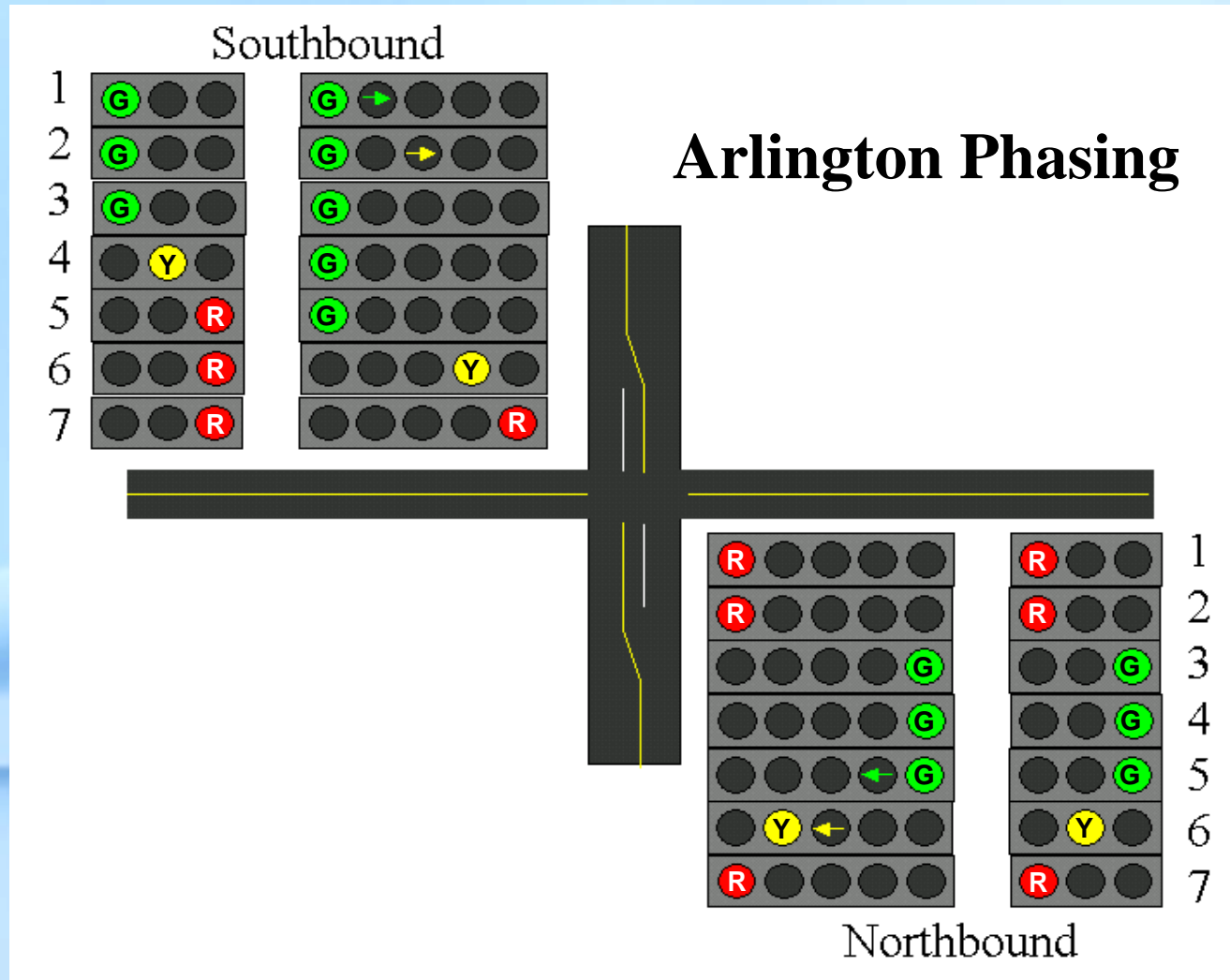
S4–Timing Adjacent Signals

- **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**

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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**
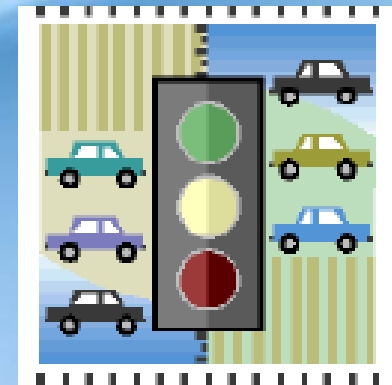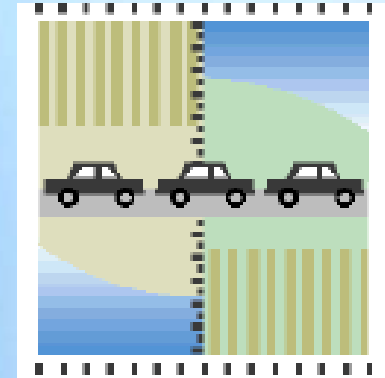
S4–Simulation Models

- **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**
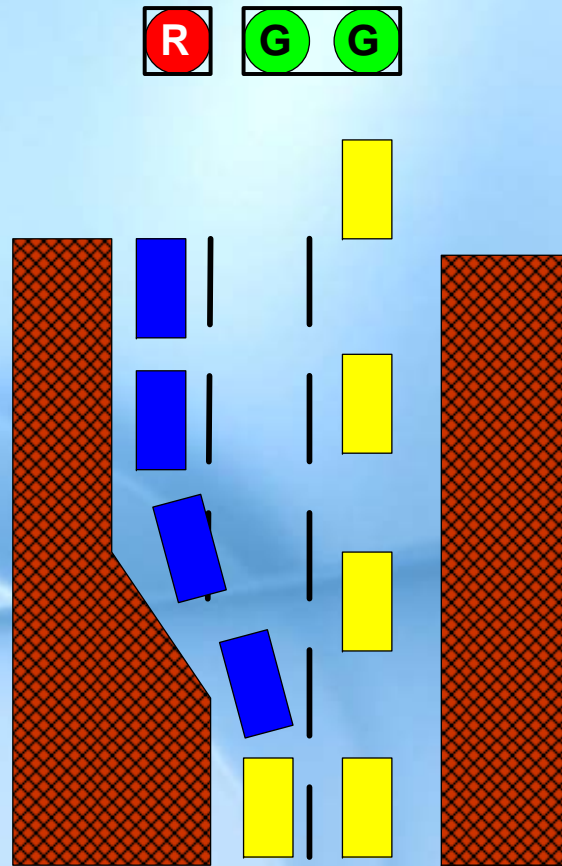
S4–Simulation Accuracy

- **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
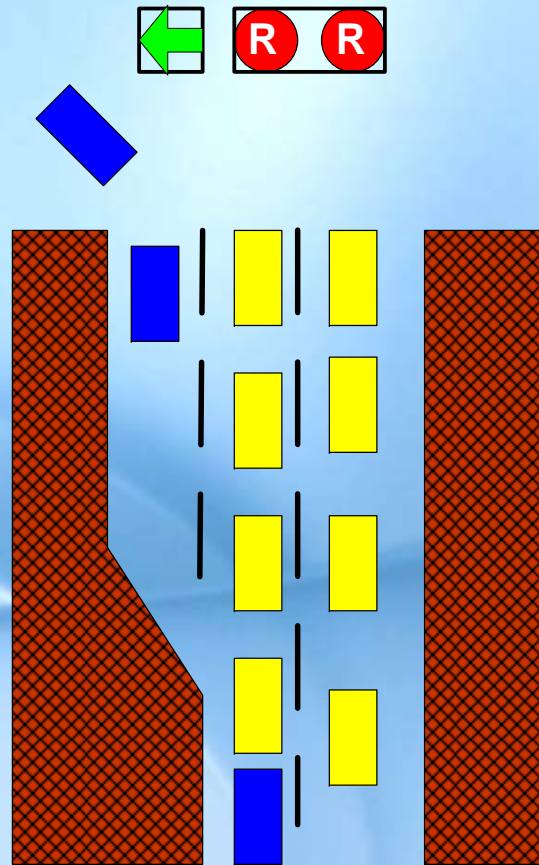
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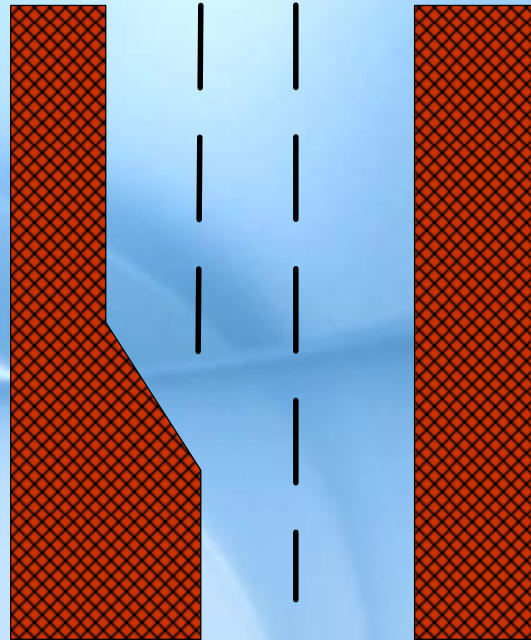
S4−Blocking and Starvation

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S4−Blocking and Starvation

(continued)

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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**

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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**

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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

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S4—Optimization Tool Types
(continued)

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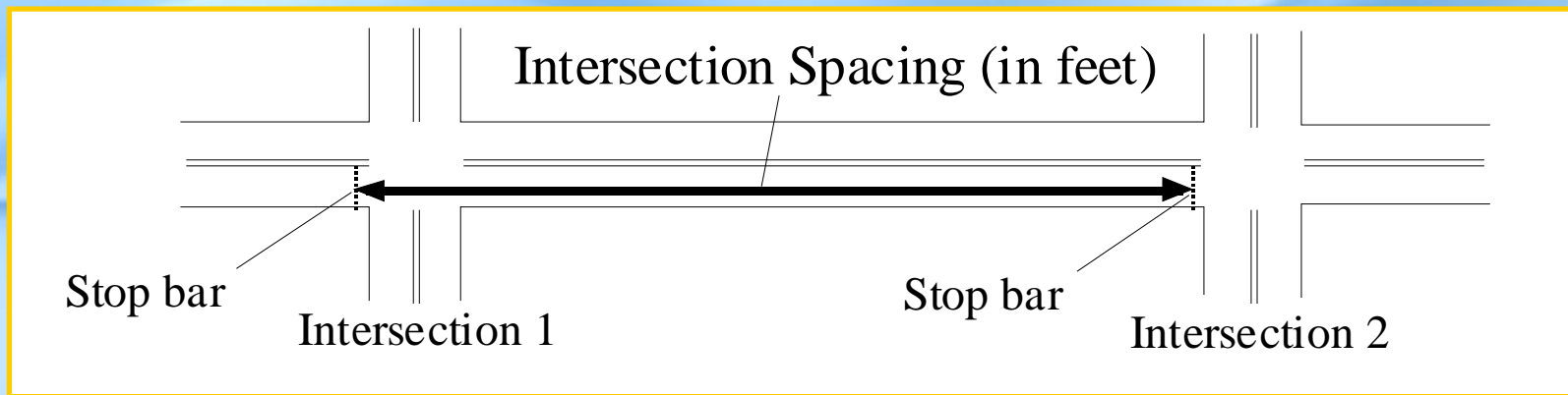 - ✓ **Simulates Traffic after Optimization**
  - ✓ **Examples:**
    - » PASSER II: Exhaustive and Heuristic
    - » PASSER IV: Mathematical Programming
    - » PASSER V: Exhaustive, Heuristic, GA

S4–PASSER V Data Needs

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

Intersection Spacing (in feet)

Stop bar

Intersection 1

Stop bar

Intersection 2
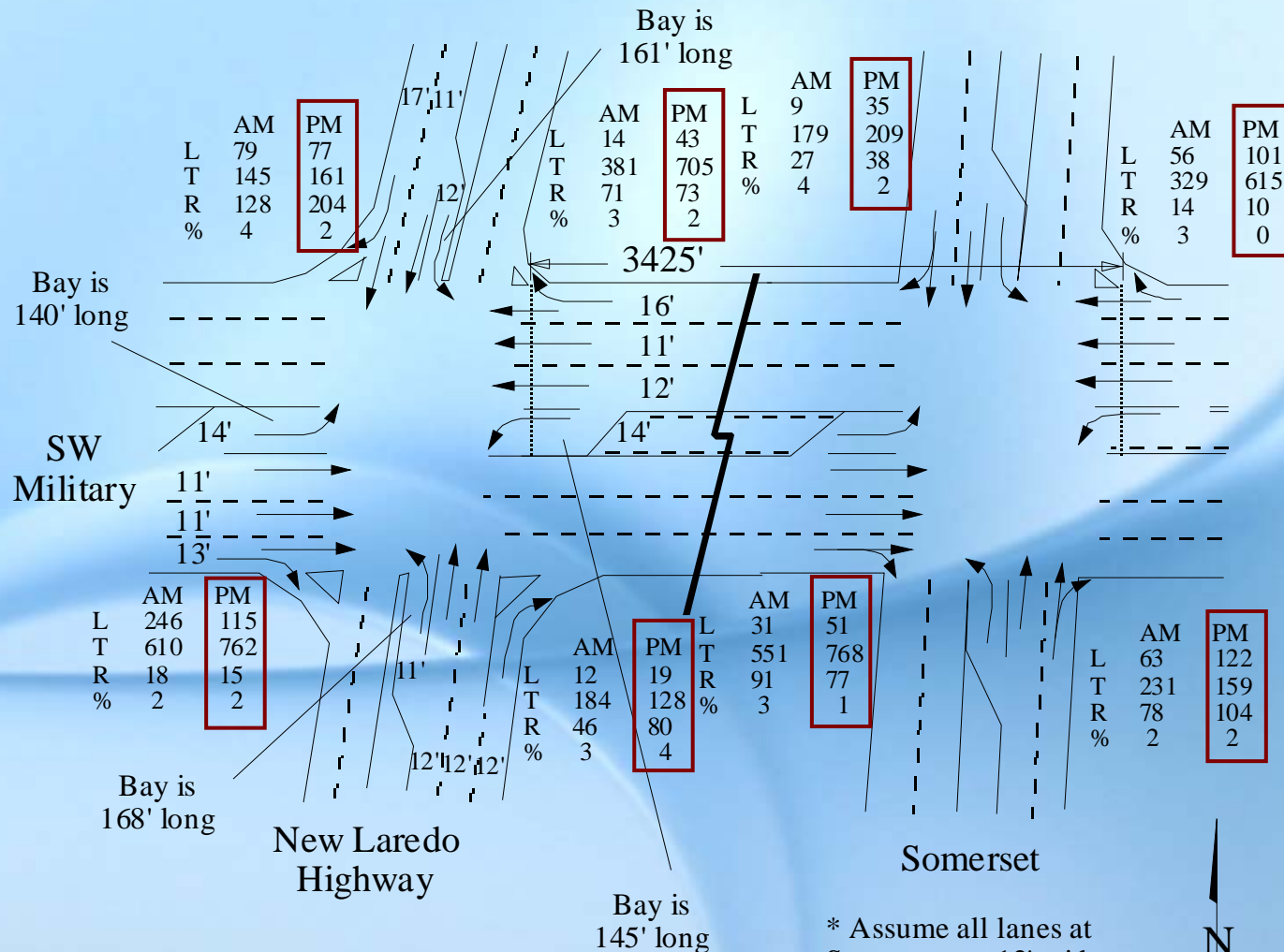
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S4–Input Performance Data

- 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
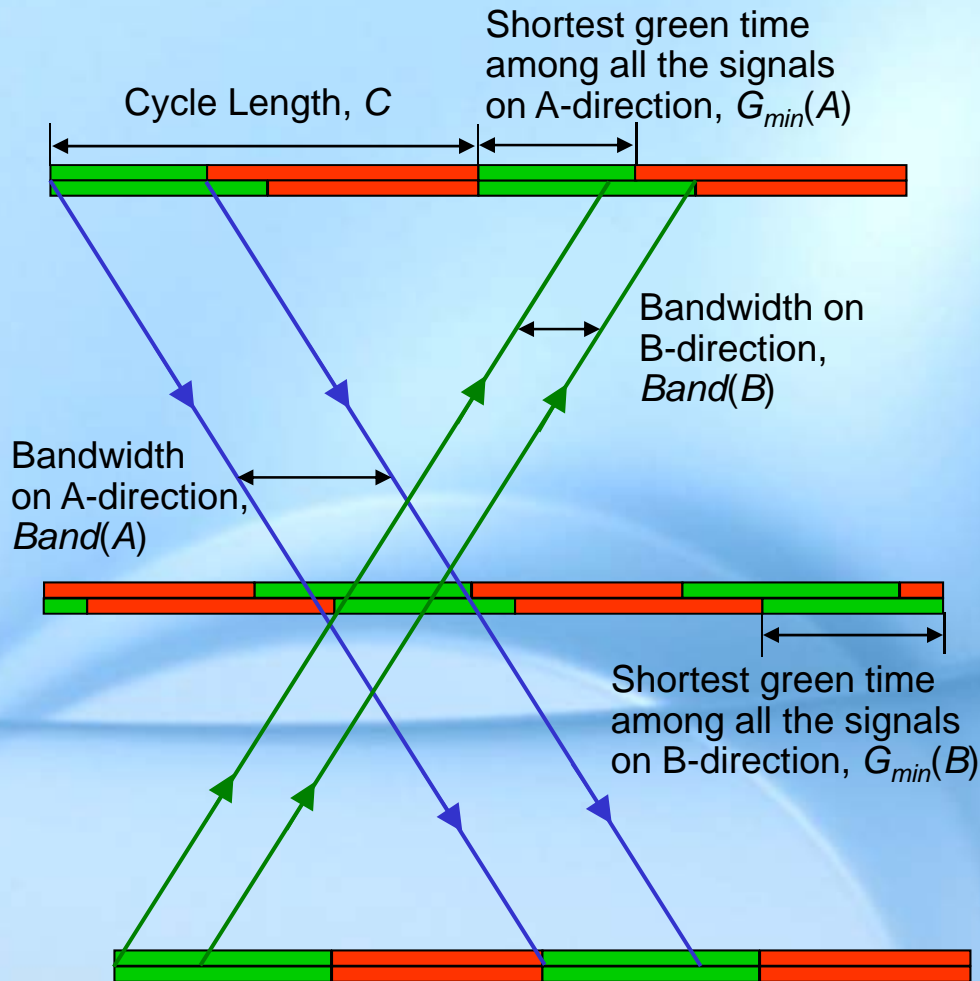
Session 5: Arterial Analysis

- **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**

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S5−Arterial Exercise 1 (User Guide, p. 130)
S.W. Military Drive, San Antonio, Texas

Bay is 161' long

	AM	PM
L	79	77
T	145	161
R	128	204
%	4	2

17' 11'

12'

	AM	PM
L	14	43
T	381	705
R	71	73
%	3	2

	AM	PM
L	9	35
T	179	209
R	27	38
%	4	2

	AM	PM
L	56	101
T	329	615
R	14	10
%	3	0

3425'

16'
11'
12'
14'
14'

Bay is 140' long

SW Military

14'
11'
11'
13'

	AM	PM
L	246	115
T	610	762
R	18	15
%	2	2

11'

12' 12' 12'

	AM	PM
L	12	19
T	184	128
R	46	80
%	3	4

	AM	PM
L	31	51
T	551	768
R	91	77
%	3	1

	AM	PM
L	63	122
T	231	159
R	78	104
%	2	2

Bay is 168' long

New Laredo Highway

Bay is 145' long

Somerset

* Assume all lanes at Somerset are 12' wide

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S5–Performance Measures

Cycle Length, C

Shortest green time among all the signals on A-direction, $G_{min}(A)$

Bandwidth on B-direction, $Band(B)$

Bandwidth on A-direction, $Band(A)$

Shortest green time among all the signals on B-direction, $G_{min}(B)$

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

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

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

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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
```
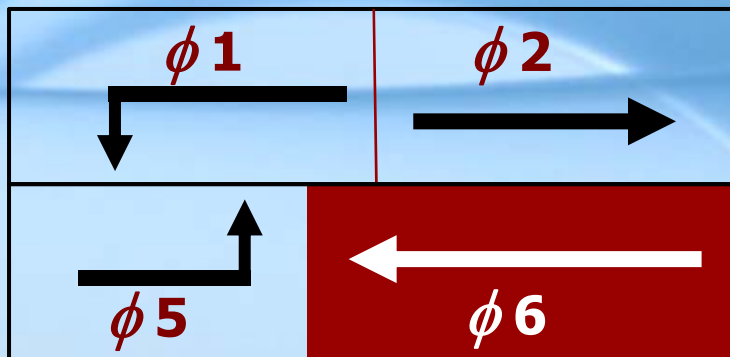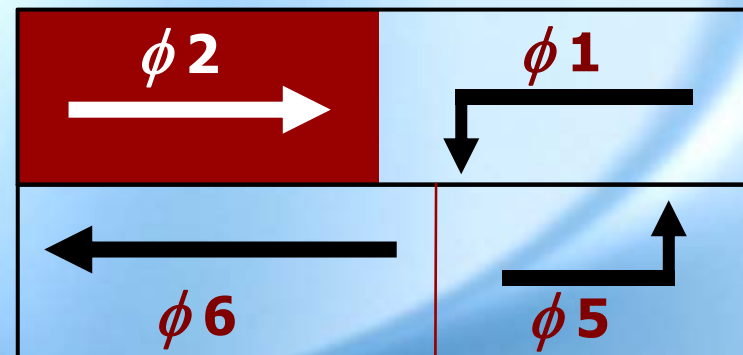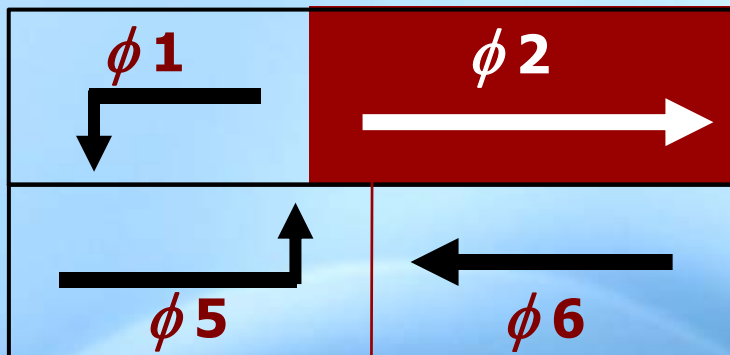
```
Spl-32 0..1...2...3...4...5...6..7..8 ->
Time     25   25  25  25  25   25  25 25
Coor-0    .    X   .   .   .    .   .  .
Mode     NON  MAX NON NON NON  MAX NON NON
```
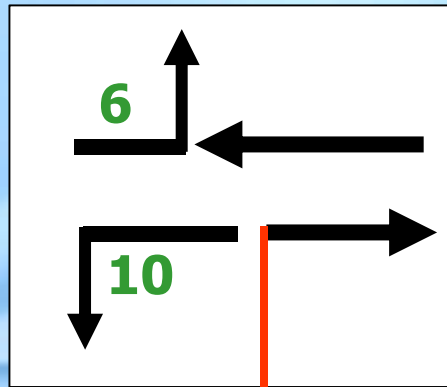
S5–NTCIP Coord Phase
(continued)

Coordinate Phase: 2

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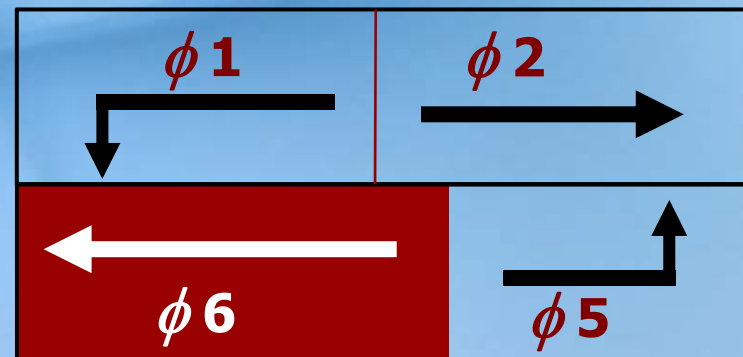
S5–Offset Adjustments

- **Lead-Lead Example**

6

10

Phase 2

Offset 10 Sec

- **Lag-Lead Example**

8
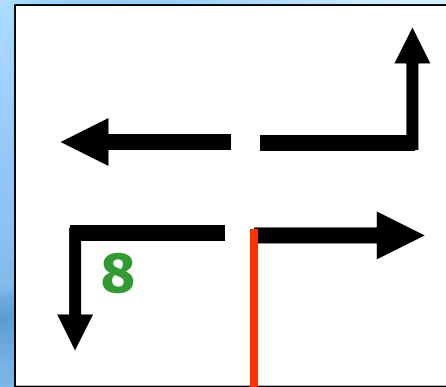
Phase 2

Offset 10 Sec

S5-Programming Sequences

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S5–Programming Sequences
(continued)

```
EPAC SEQUENCE   1 (ALT SEQ   0)
          PHASE SEQUENCE BY RING              .
PHSE ## ## ## ## ## ## ## ## ## ## ## ##
 R1-  01-02 03-04 00-00  00-00  00-00  00-00
 R2-  05-06 07-08 00-00  00-00  00-00  00-00
 R3-  00-00 00-00 00-00  00-00  00-00  00-00
 R4-  00-00 00-00 00-00  00-00  00-00  00-00
A-UP B-DN              E-EDIT  F-PRIOR MENU
```

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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	

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S5–How Genetic Algorithm (GA) Works

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

  Parents

  Offspring

- **Evaluate Each Using Simulation**
  - ✓ **Note Population Has Doubled**

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S5–How GA Works *(continued)*

- **Keep Best Half of New Population**

Parents   **Offspring**
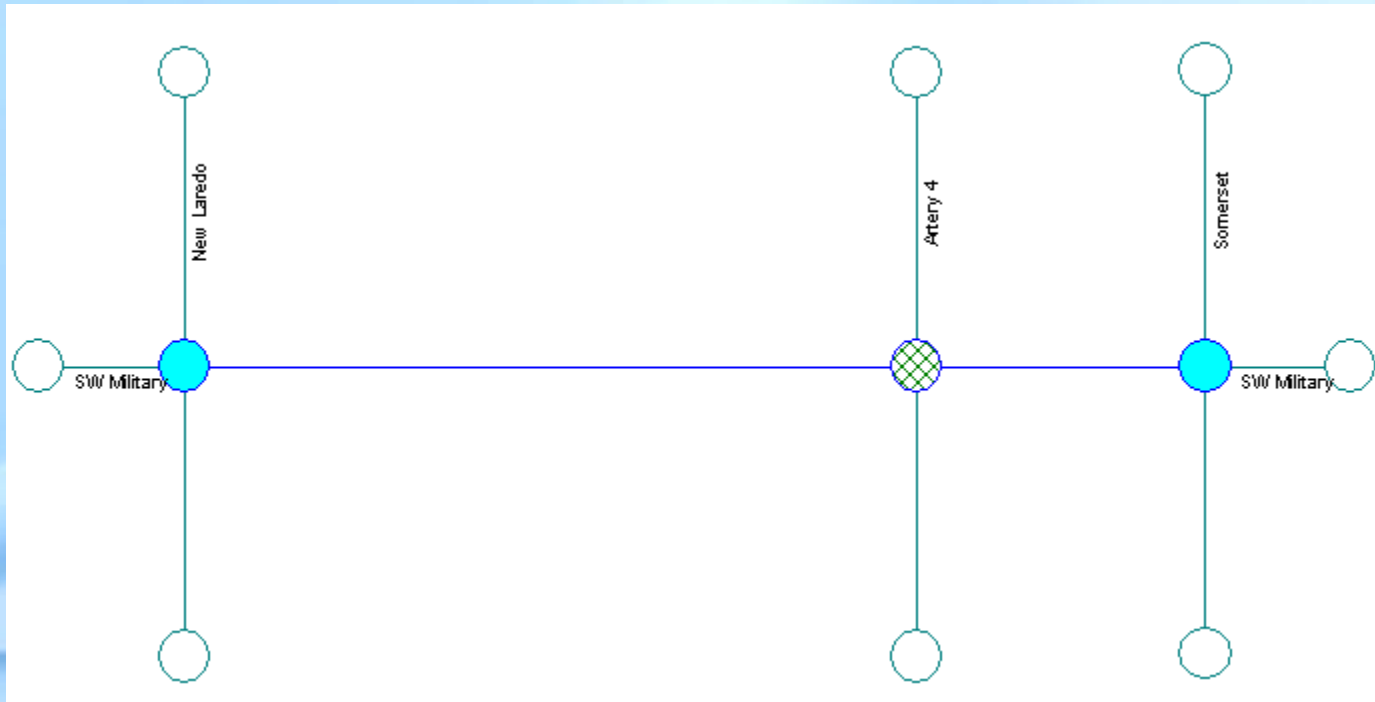
- **Perform Mutation Operation**

Next Generation

S5–How GA Works (continued)

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

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S5–Arterial Exercise 2

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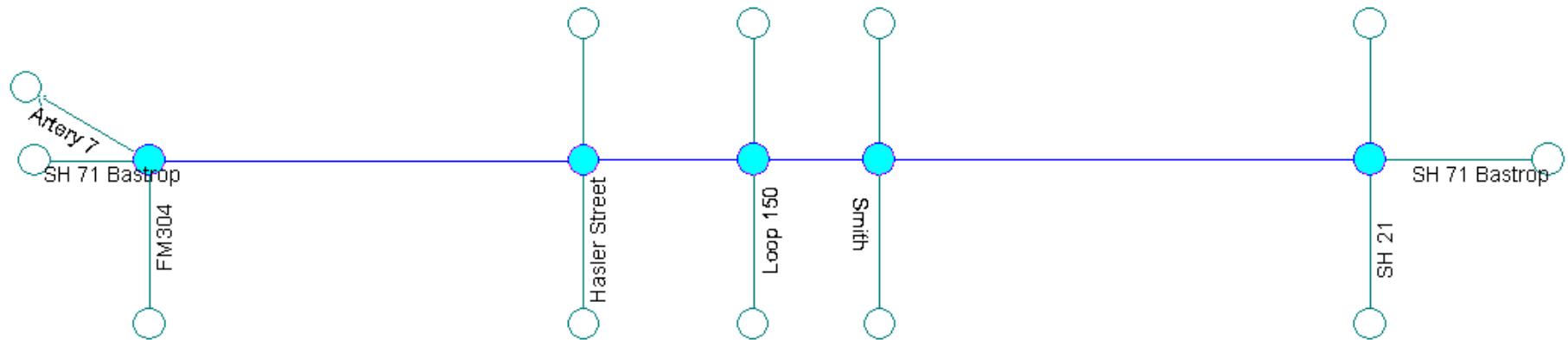
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S5–More Theory

- **Handling of TWSC Intersections on Arterial**
  - ✓**Upstream Signals**
    - » Platoon Dispersion
  - ✓**Handling in Various Tools**
    - » PASSER II
    - » Other Tools (Except P3)
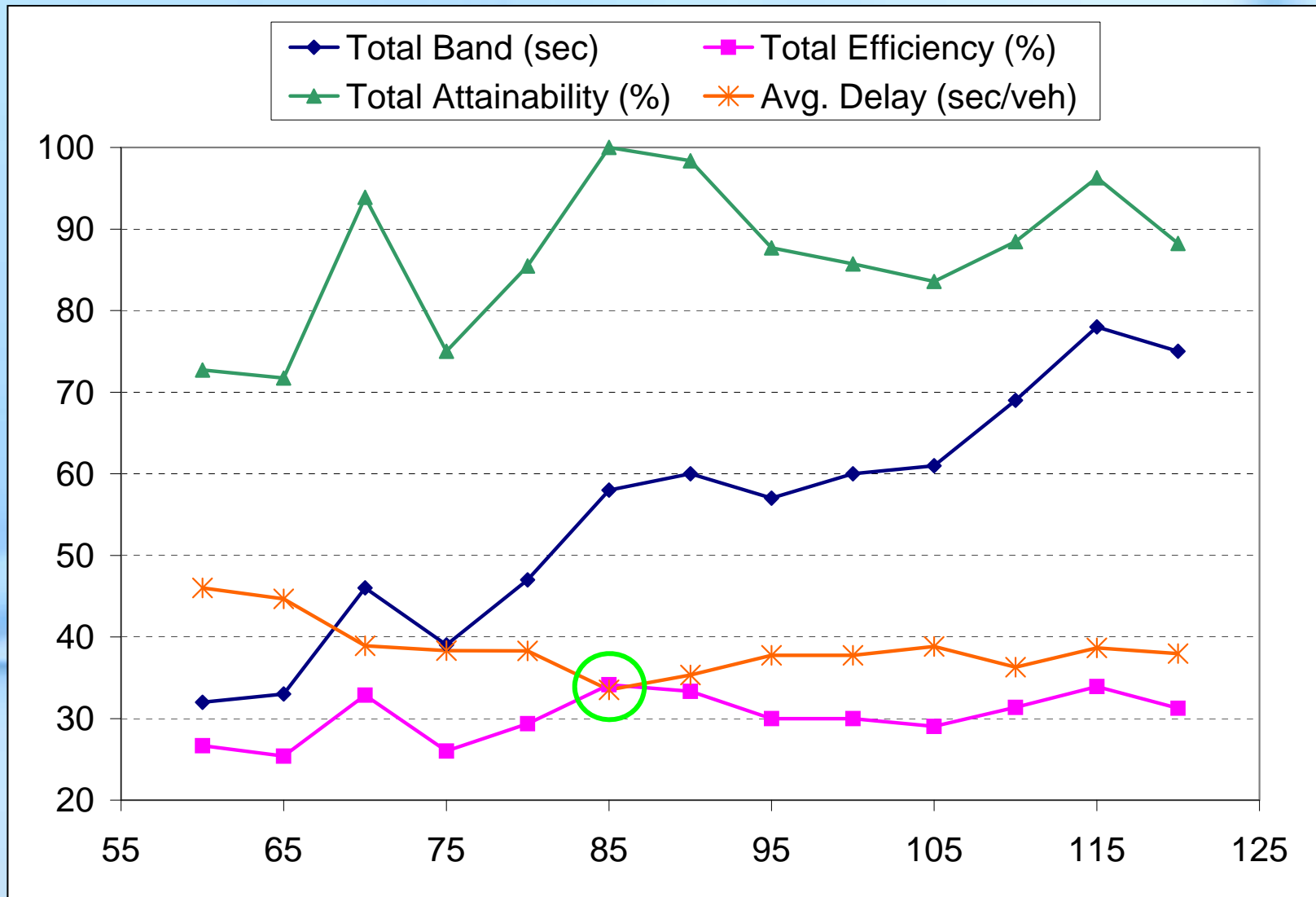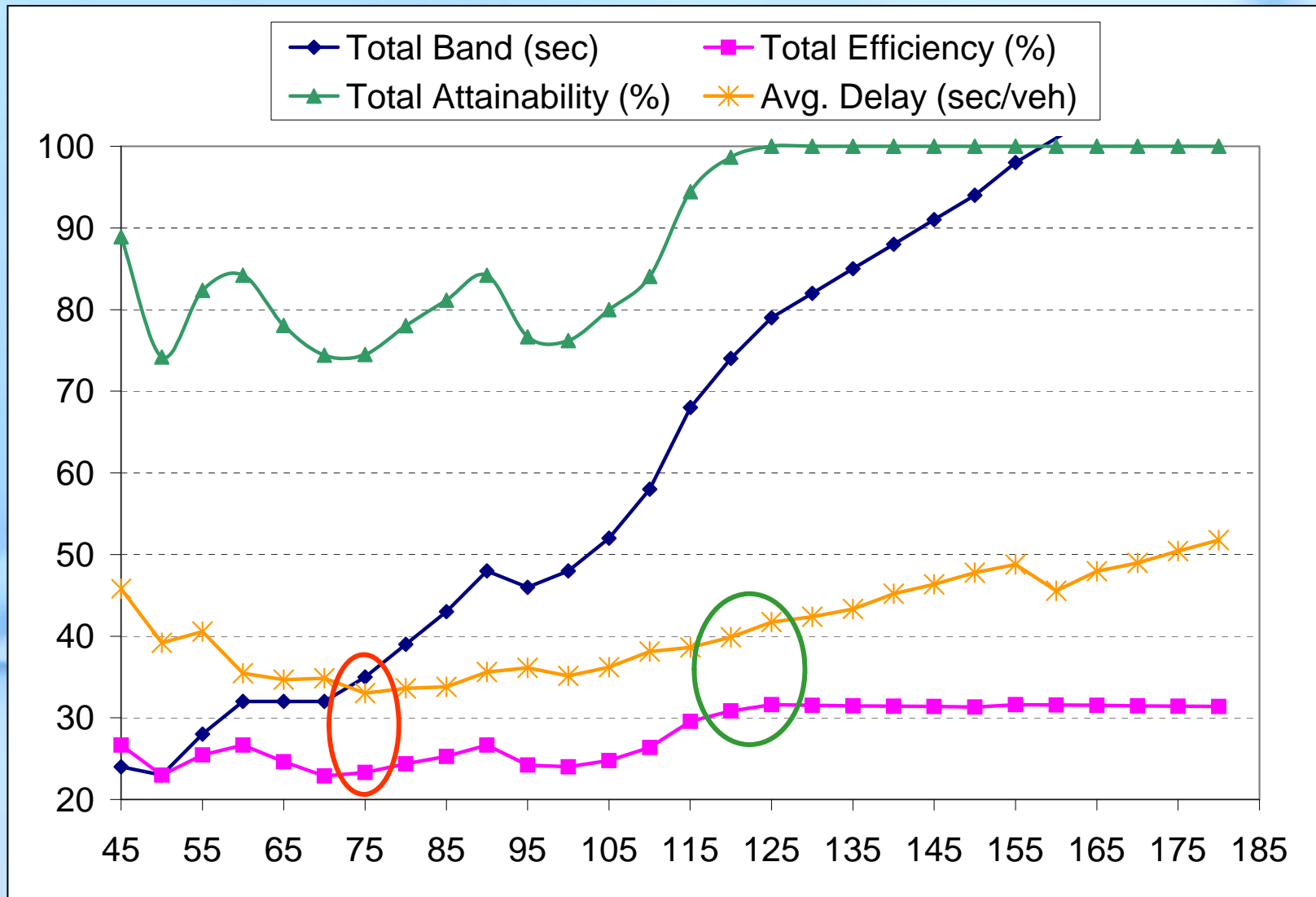
S5–Arterial Exercise 3

SH 71, Bastrop, Texas

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S5–Bandwidth vs. Efficiency

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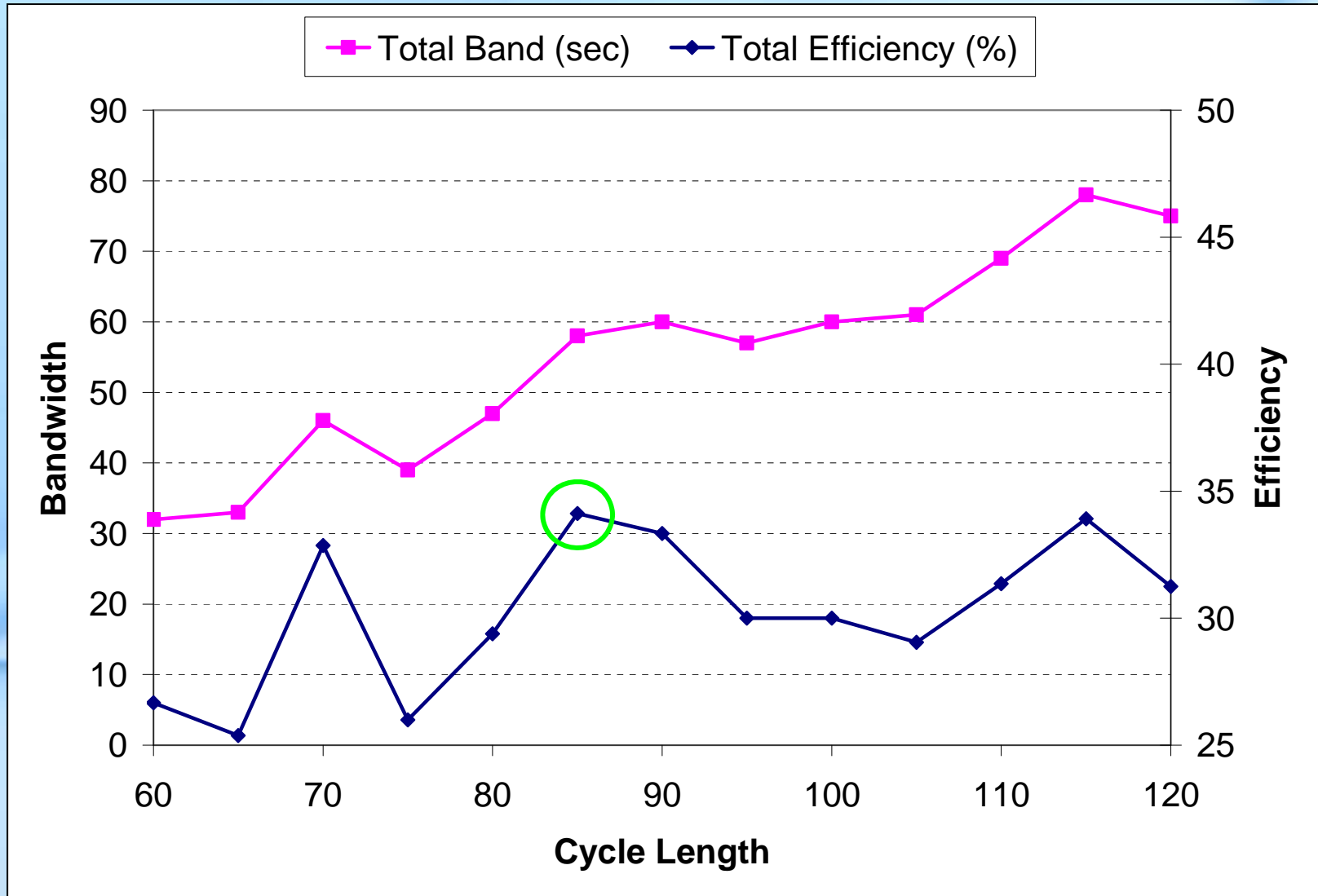
S5–Delay and Attainability

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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**

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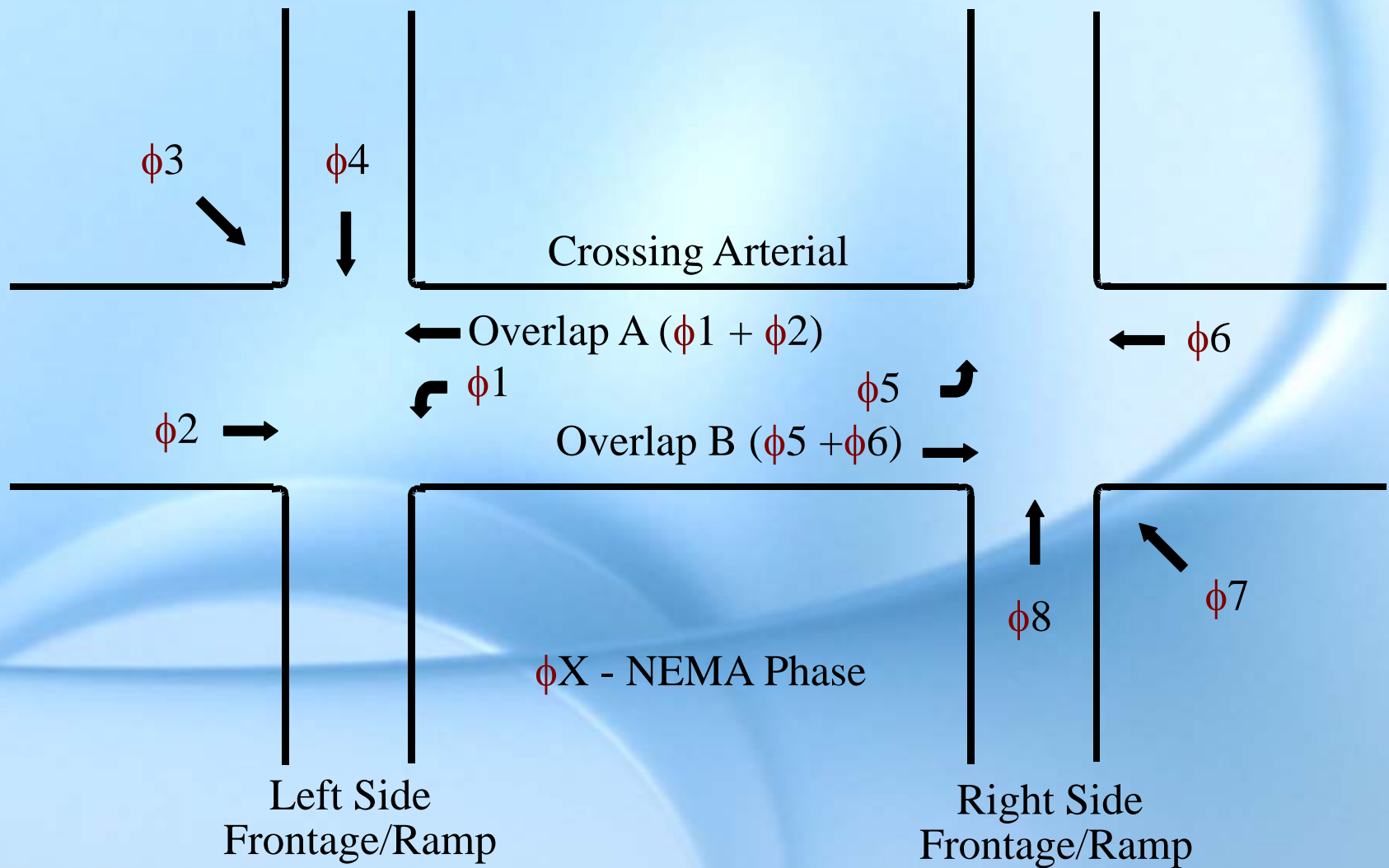
S6–Background on Diamonds

- **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)**
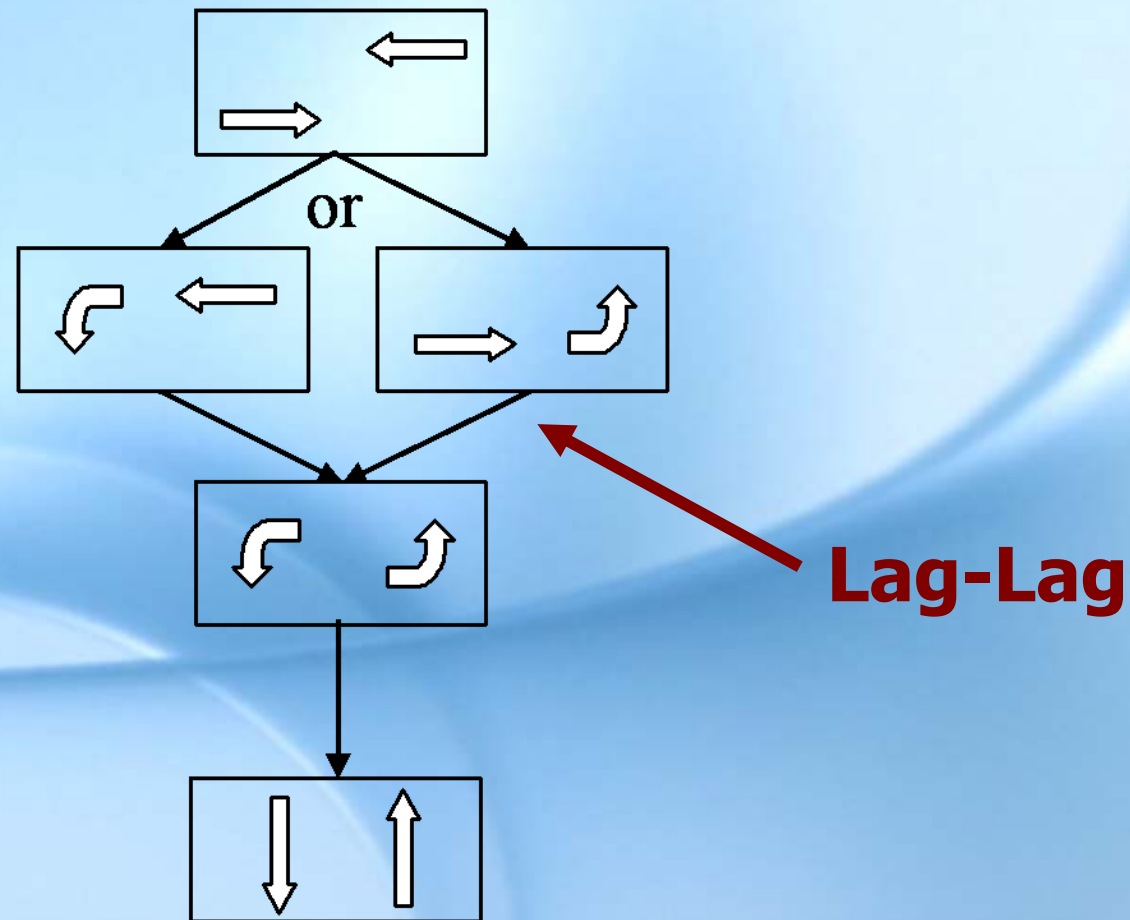
S6—Background on Diamonds
(continued)

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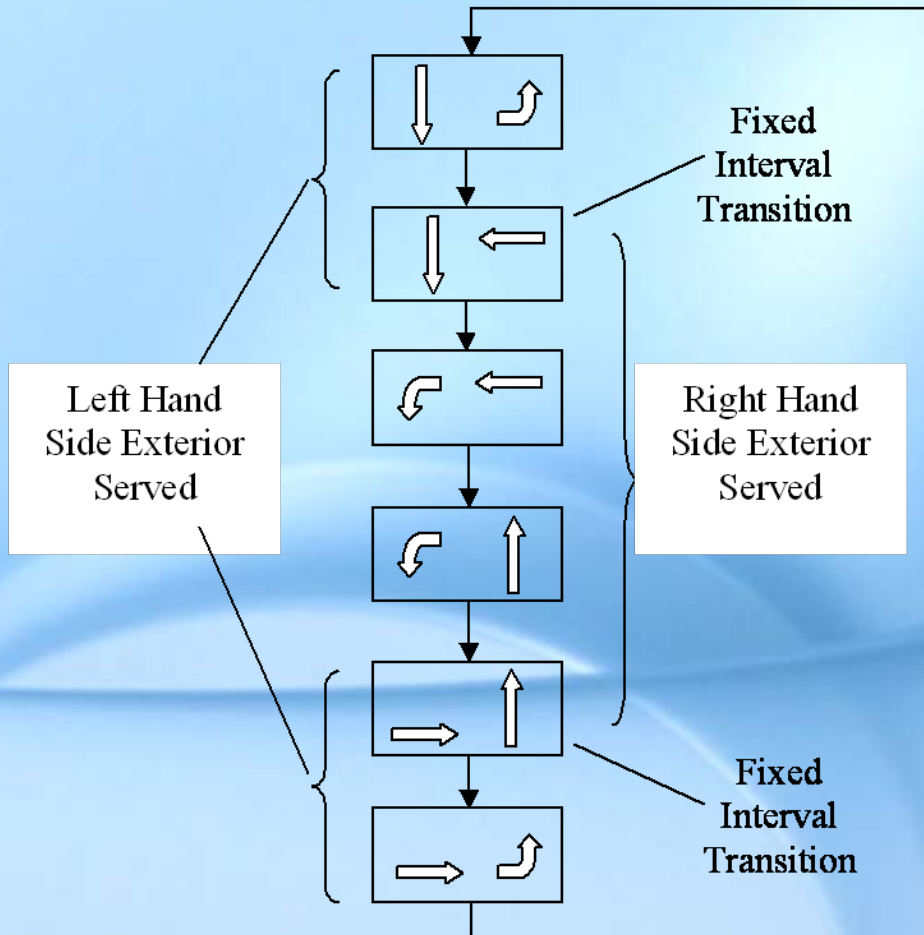 - ✓ **Separate Intersection Mode**

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S6−NEMA Phase Numbering

$\phi3$ $\phi4$

Crossing Arterial

← Overlap A ($\phi1 + \phi2$)

← $\phi6$

$\phi1$ $\phi5$

$\phi2$ → Overlap B ($\phi5 + \phi6$) →

$\phi8$ $\phi7$

ϕX - NEMA Phase

Left Side
Frontage/Ramp

Right Side
Frontage/Ramp

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S6 – Three-Phase Operation

Lag-Lag

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S6–Four-Phase Operation

- **Lead-Lead Phasing**
- **Phase Times and Offset Calculated Simultaneously**
- **Needs Longer Cycle**
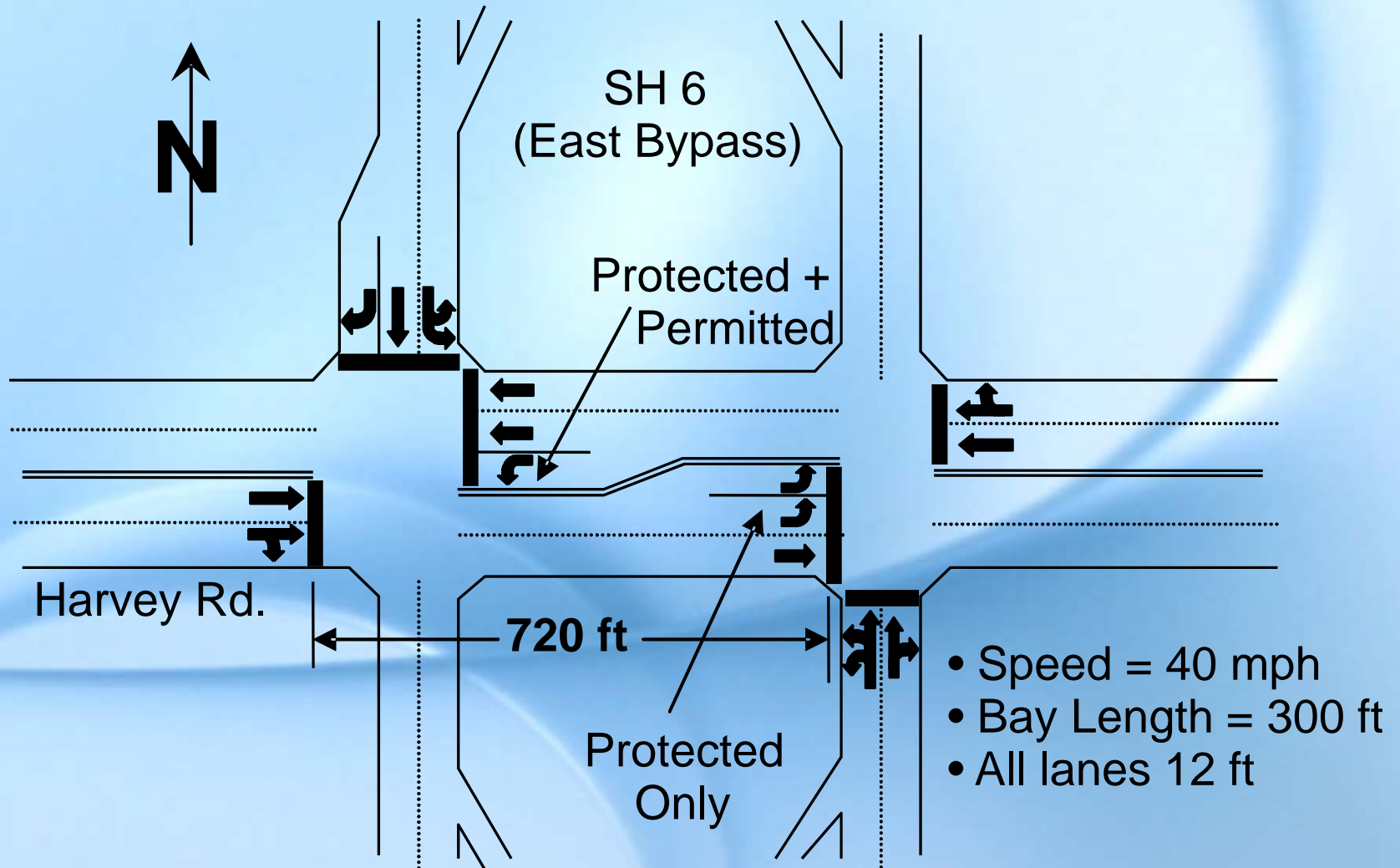
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S6 – Other Options

- **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)

N

SH 6
(East Bypass)

Protected +
Permitted

Harvey Rd.

← 720 ft →

Protected
Only

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

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S6–Data Entry/Analysis

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

Texas
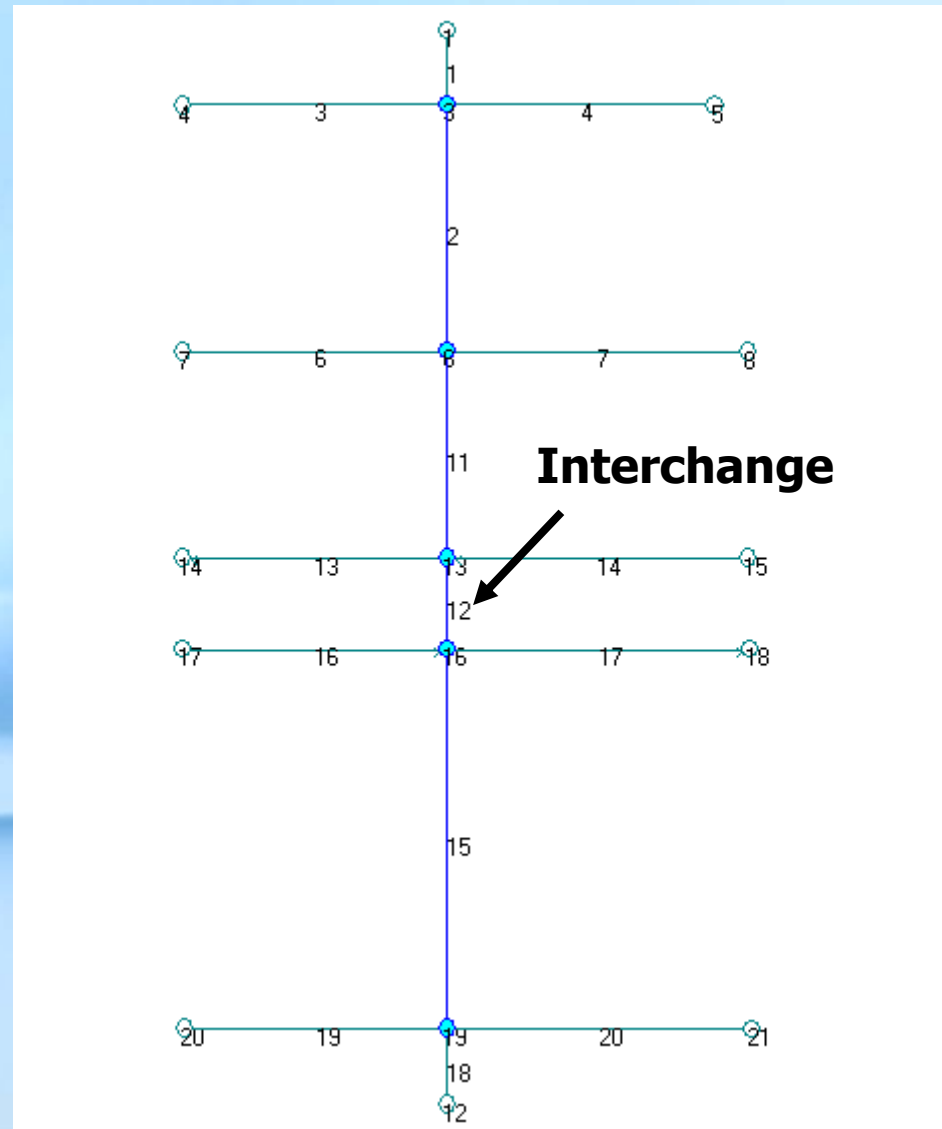Transportation
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S6 – More Tools in PASSER V

- **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

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Session 8: Workshop Conclusion

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