DETECTION-CONTROL SYSTEM (D-CS)

Dan Middleton, Ph.D., P.E.
Texas A&M Transportation Institute
Texas A&M University
College Station, TX

Outline

- Introduction
  - Methods of intersection control
  - Conditions where D-CS is appropriate
- Early deployment of D-CS
  - TxDOT results
  - FHWA results
- Discussion

Methods of Dilemma Zone Protection

- No detection upstream (stop line only)
- Single advance detectors
- Multiple advance detectors
  - Inductive loops
  - Magnetometers
  - Other point detectors
- Wavetronix SS-200 “Advance”
- Hybrid Detectors
- Detection-Control System

Single Advance Detectors

- Advantages
  - Well known concept
  - Quicker installation than multiple detectors
- Disadvantages
  - Loop failure rates may be high
  - Potential damage from roadside work
  - Exposure to traffic
  - Less efficient than multiple detectors
  - No special consideration for trucks

Multiple Advance Detectors

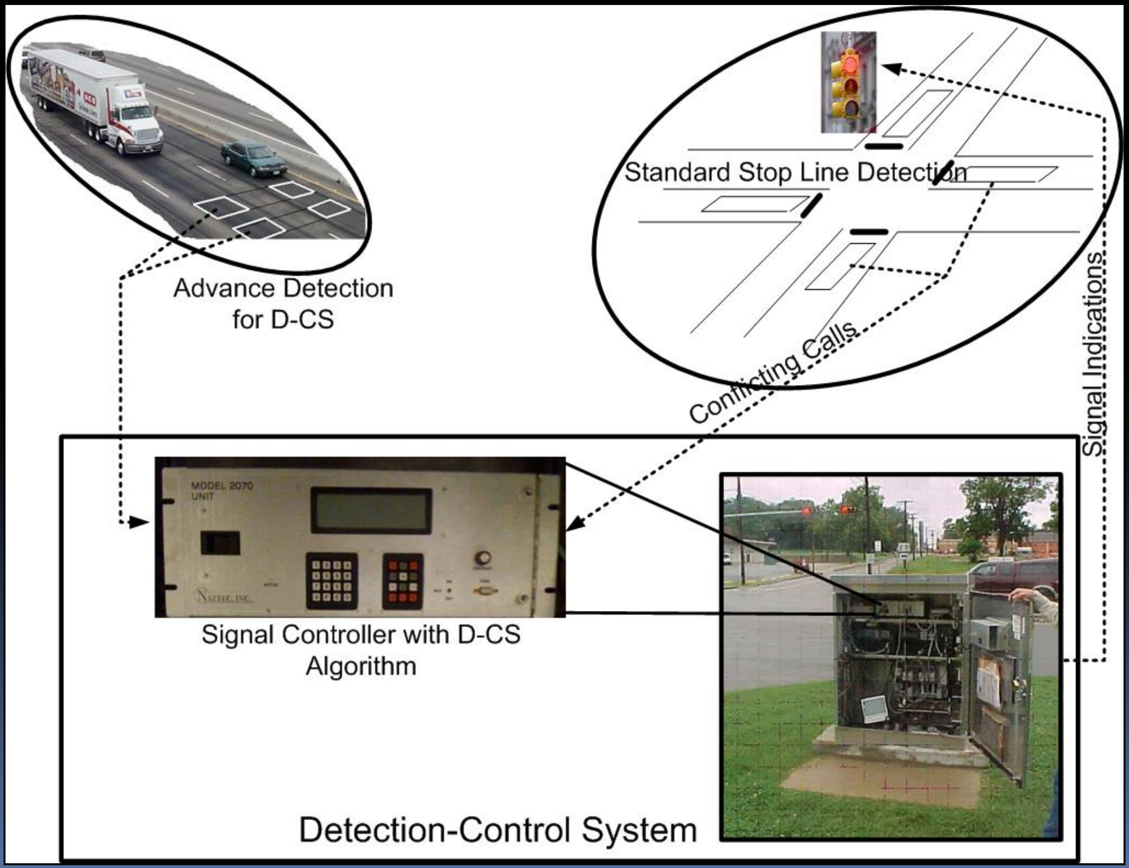
- Advantages
  - Well known concept and components
- Disadvantages
  - Loop failure rates may be high
  - Potential damage from roadside work
  - Exposure to traffic
  - Might not find adequate gap in high demand situations
  - No special consideration for trucks

Wavetronix Advance (SS-200)

- Advantages
  - Nothing in the pavement
  - Simple setup
  - Tracks vehicles in real time
  - Adapts to variations in vehicle speeds
- Disadvantages
  - Requires bucket truck to install
  - No left- or right-turn detection
  - Does not detect vehicles by lane
  - SS-200 max range is 600 ft from detector
  - Does not distinguish trucks (although SS200E does)
  - Indirect consideration of minor movements

Early Deployment of D-CS

- TxDOT Research
- FHWA Research



Background

- D-CS came from two different directions:
  - Need for a better system for high-speed signalized intersections
  - Mandatory speed reductions in Houston District

D-CS Overview

- Background
- Early development
- Modifications and additions
  - What worked
  - What didn't work

Detection-Control System

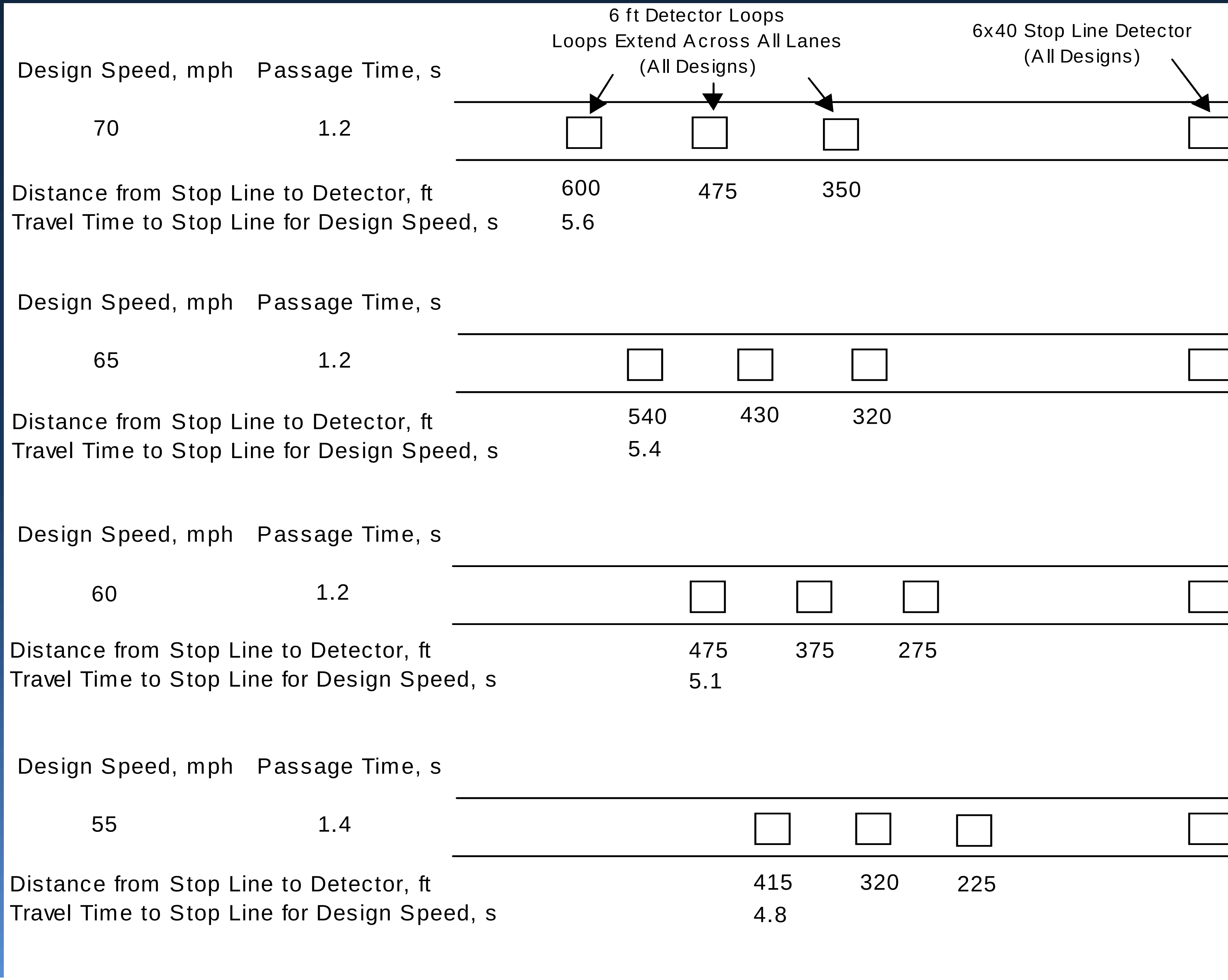
- Assumptions:
  - Vehicle speed remains constant on approach to signal
  - Stopped queue has cleared before dilemma zone protection can begin
  - The earlier green ends, the better for minor movements
  - Ability to "look ahead" and find time to end limited by fastest vehicle speed

Early Modifications

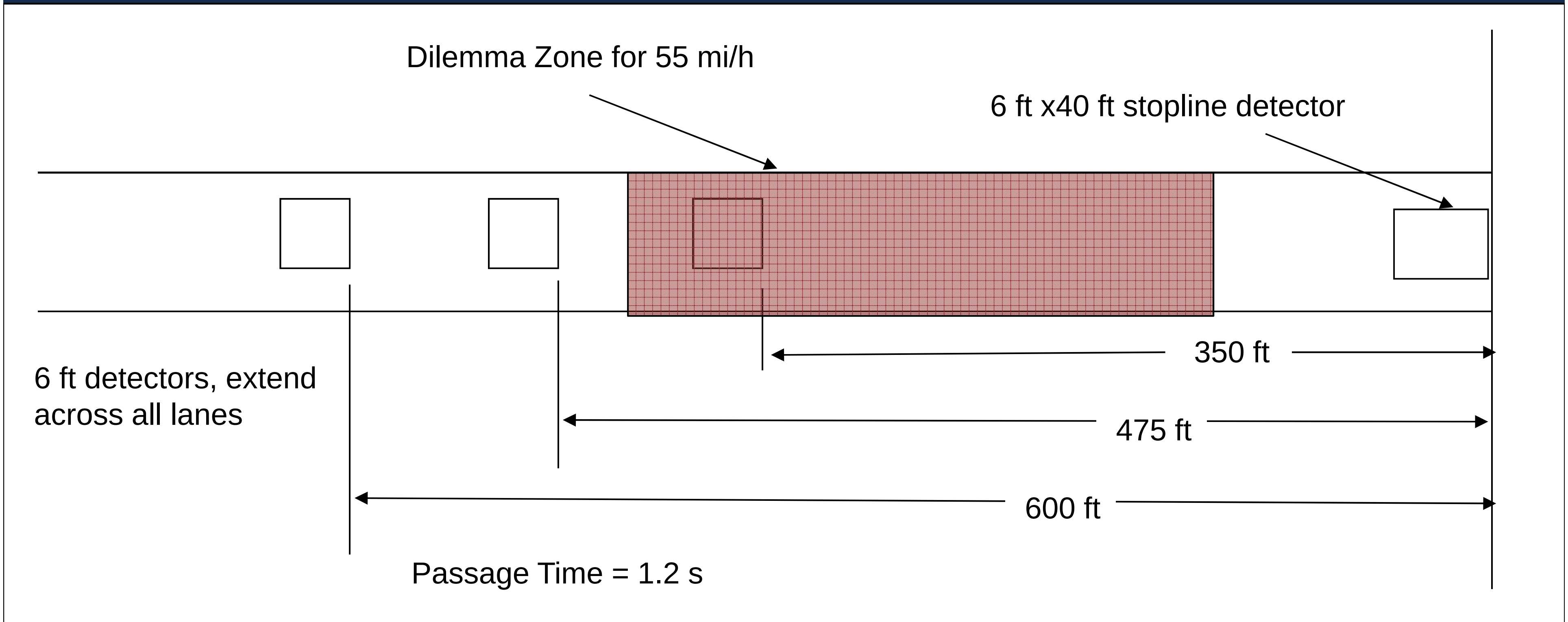
- Two-stage control
  - Stage 1: D-CS must have empty dilemma zones to end phase
  - Stage 2: Up to one passenger car (NOT truck) may be in a dilemma zone in each lane and still have the phase end
- Dealing with external control lag
- PC-related issues and timing
- Dealing with external control quirks

Ideas That Worked

- Separate dilemma zones for cars and trucks
  - Truck drivers decide farther away from the intersection
  - To allow for this:
    - Car dilemma zones: 5.5 s – 2.5 s
    - Truck dilemma zones: 7.0 s – 2.5 s


6 ft Detector Loops
Loops Extend Across All Lanes
(All Designs)
6x40 Stop Line Detector
(All Designs)
Design Speed, mph
Passage Time, s
70
1.2
Distance from Stop Line to Detector, ft
Travel Time to Stop Line for Design Speed, s
600
475
350
5.6
Design Speed, mph
Passage Time, s
65
1.2
Distance from Stop Line to Detector, ft
Travel Time to Stop Line for Design Speed, s
540
430
320
5.4
Design Speed, mph
Passage Time, s
60
1.2
Distance from Stop Line to Detector, ft
Travel Time to Stop Line for Design Speed, s
475
375
275
5.1
Design Speed, mph
Passage Time, s
55
1.4
Distance from Stop Line to Detector, ft
Travel Time to Stop Line for Design Speed, s
415
320
225
4.8

TxDOT 70 mi/h design



Speeds protected: 70 mi/h → ~58 mi/h

A vehicle traveling 55 mi/h cannot continuously actuate the existing detectors!

Detection-Control System

- Advantages
  - One detector layout for all speeds
  - Can protect vehicles of any type
  - Easy to specify on plans
- Disadvantages
  - Setup is critical
  - Needs algorithm running within controller or using external inputs
  - Major-minor isolated intersection only
  - Detector failures may cause considerable system degradation

General Guidance on D-CS Use

- Isolated full-actuated intersection
- Intersection of major road & minor road
- 85th percentile speed (or speed limit) > 45 mph
- Total turn percentage (right plus left) <40%
- Truck traffic >10% (off-peak) or >5% (peak)
- Crash rates (rear-end & right angle) > similar local intersections

Comparison of Advance with D-CS

Wavetronix Advance	D-CS
Non-intrusive	Intrusive (loops, magnetometers)
Tracking (real-time)	Point detection
Area detection	Detection by lane
Classifies 80% of trucks	Classifies 95% of trucks
Requires bucket truck	Requires lane closure
Considers side-street delay indirectly	Considers side-street delay directly
Uncertain of accuracy in high volume	Works well in high speed, high volume
Uncertain of readiness for Conn. Veh.	Connected Vehicle potential
No special controller required	Requires special controller

TxDOT Evaluation of D-CS

- D-CS:
  - Reduces number of vehicles caught in DZ
  - Reduces number of trucks caught in DZ
  - Reduces frequency of RLR
  - Potentially reduces overall delay

TxDOT Implementation

Implementation Site [a]	Nearest City	Major-Road Characteristics			Years With Signal	D-CS Installation Date
		Name	Through Lanes	Advance Detection [b]		
Loop 340/F.M. 3400	Waco	Loop 340	2	None	>4	March 2003
U.S. 84/Williams Rd.	Bellmead	U.S. 84	4	Unsignalized	0	October 2003
U.S. 82/F.M. 3092	Gainesville	U.S. 82	4	Loop	>6	June 2003
U.S. 82/Weber Dr.	Gainesville	U.S. 82	4	Video	>6	July 2003
U.S. 59/F.M. 819	Lufkin	U.S. 59	4	Video	>4	June 2004
U.S. 281/Borgfeld Rd.	San Antonio	U.S. 281	4	Loop	1.5	August 2004
U.S. 84/F.M. 2837	Waco	U.S. 84	4	Loop	>3	January 2005
U.S. 59/F.M. 3129	Domino	U.S. 59	4	Video	>6	April 2005

[a]Sites identified by underline were evaluated in the before-after study.
[b]Advance detection used prior to the installation of D-CS. Loop: multiple advance inductive loop detectors. Video (video imaging detection system): multiple advance video detection zones.

TxDOT Findings: RLR

Site	Approach	Red-Light Violations (all vehicles)[a]			Red-Light Violations (heavy vehicles)[a]		
		Expected in "After" Period, (veh)	Observed in "After" Period, (veh)	Relative Change,[b] (%)	Expected in "After" Period, (veh)	Observed in "After" Period, (veh)	Relative Change,[b] (%)
Loop 340 & F.M. 3400	Northbound	13.5	1	-93	4.3	0	-100
	Southbound	6.6	1	-85	1.9	1	-46
U.S. 82 & F.M. 3092	Eastbound	7.6	9	**19**	1.9	1	-46
	Westbound	11.8	6	-49	3.3	1	-69
U.S. 82 & Weber Dr.	Eastbound	5.2	2	-61	1.6	1	-37
	Westbound	4.7	2	-57	1.3	1	-22
U.S. 59 & F.M. 819	Northbound	16.7	7	-58	3.3	1	-69
	Southbound	24.2	5	-79	8.6	0	-100
U.S. 281 & Borgfeld Rd.	Northbound	38.3	19	-50	1.9	0	-100
	Southbound	22.7	11	-52	2.1	0	-100
Overall:		151.2	63	-58	30.0	6	-80
Loop 340:		20.1	2	-90	6.2	1	-84
All sites but Loop 340:		131.2	61	-53	23.8	5	-79

[a] Frequency of red-light violations during study.

[b] Relative change = (Obs. After/Exp. After −1) × 100. Negative values of relative change indicate a reduction in violation frequency. Underlined values are statistically significant at 95 percent level of confidence.

TxDOT Findings: Crashes

Site	"Before" Study Period		Expected Crashes in "After" Period	"After" Study Period		Relative Change,[a] %
	Years	Crashes		Years	Crashes	
Loop 340/F.M. 3400	3.0	10	3.8	0.83	3	-21
U.S. 82/ F.M. 3092	3.0	7	4.2	1.67	4	-6
U.S. 82/Weber Dr.	3.0	8	4.3	1.58	2	-53
U.S. 59/F.M. 819	3.0	23	5.2	0.67	3	-42
U.S. 281/Borgfeld Rd.	1.5	13	5.5	0.58	2	<u>-64</u>
Overall:	13.5	61	23.0	5.33	14	<u>-39</u>

[a] Relative change = (Obs. After/Exp. After −1) × 100. Negative values of relative change indicate a reduction in crash frequency. <u>Underlined</u> values are statistically significant at 95 percent level of confidence.

TxDOT Findings: Delays & Stops

Site	Approach	Total Control Delay			Total Vehicles Stopping		
		Expected in "After" Period, (hours)	Observed in "After" Period, (hours)	Relative Change, [a, b] (%)	Expected in "After" Period, (veh)	Observed in "After" Period, (veh)	Relative Change, [a, b] (%)
Loop 340 & F.M. 3400	Northbound	2.0	1.6	-20	289	217	-25
	Southbound	1.4	1.5	7	230	190	-17
U.S. 82 & F.M. 3092	Eastbound	6.8	6.4	-7	748	654	-13
	Westbound	7.3	6.4	-12	802	711	-11
U.S. 82 & Weber Dr.	Eastbound	0.4	0.3	-42	73	51	-30
	Westbound	0.4	0.2	-44	75	46	-38
U.S. 59 & F.M. 819	Northbound	15.7	13.2	-16	1324	1221	-8
	Southbound	14.2	11.5	-19	1315	1237	-6
U.S. 281 & Borgfeld Rd.	Northbound	3.2	1.6	-49	484	283	-42
	Southbound	6.5	7.4	13	753	953	26
Overall:		58.0	50.0	-14	6093	5563	-9

[a] Relative change = (After/Before −1)× 100.

[b] Negative values denote a reduction. Underlined values are statistically significant at 95 percent level of confidence.

FHWA Evaluation of D-CS

Site Description	Near City, State	Cabinet Type	Controller
U.S. 27/Pines Blvd	Ft. Lauderdale, FL	Naztec TS-2	Naztec 2070L
U.S. 27/Griffin Rd.	Ft. Lauderdale, FL	Naztec TS-2	Naztec 2070L
U.S. 27/Johnson St.	Ft. Lauderdale, FL	Naztec TS-2	Naztec 2070L
U.S. 24/Main St.	Peoria, IL	Naztec TS-2	Naztec 2070L
U.S. 24/Cummings La.	Peoria, IL	Naztec TS-2	Naztec 2070L
La 3162/La 3235	New Orleans, LA	Naztec TS-2	Naztec 2070L
U.S. 281/E. Borgfeld Dr.	San Antonio, TX	Eagle TS-2	Naztec 2070L
U.S. 84/Speegleville Rd.	Waco, TX	Eagle TS-1	PC with D-CS

FHWA: RLR Violation Rates[a]

Observation Period	RLR per 1,000 vehicles	RLR per 10,000 veh-cycles
Before	9.0	1.9
After	1.6	0.3
Percent Change [b]	-82	-82
Average [c]	5.3	1.1

[a] Overall average rates based on total observations for all sites.
[b] Percent change = 100 x (After/Before - 1.0).
[c] RLR per 10,000 veh-cycle = count of red-light violations x 10,000 x Σ study hours / (Σvehicles x Σcycles).

FHWA: Total Violation Rates

Observation Period	Cycles	Flow Rate [a], veh/h	Cycle Length [b], sec	No. of RLR Violations [a], veh	No. of Vehicles in the DZ [a]	No. of Max Outs
Before	663	8511	81	75	161	30
After	648	8430	81	13	45	11
% Change [c]	-2.3	-1.0	0.0	-82	-73	-51
Total	1,311	16,941	81	88	206	41

[a] Flow rate and counts include all vehicles, including passenger cars and heavy vehicles.
[b] Cycle length represents an average length.
[c] Percent change = 100 x (After/Before - 1.0)

FHWA: Conclusions

- D-CS
  - Reduced RLR by 82 percent
  - Reduced vehicles in DZ by 73 percent
  - Reduced max-outs by 51 percent
- Naztec was only controller
  - One D-CS manufacturer was a limitation
  - Research results should encourage others

CURRENT FHWA D-CS DEPLOYMENT

D-CS Deployment Objectives

- Improve safety at rural high speed signalized intersections
- Make D-CS technology available to all states
  - Affordable cost
  - Wider availability in other controller platforms
- Develop marketing and training material

Framework of Design Specifications

- Minimum level of vehicle detection
- Required controller processing power
- Selection of vehicle detection technologies
- Unified signal phase to speed trap mapping
- Unified data structure of vehicle information
- D-CS module
- Diagnose and failure handling module

D-CS Implementation

- New platforms representing future direction of signal controller technologies (CV)
- Support firmware upgrade
- Legacy platforms with large installation bases at rural high speed intersections
- Affordable implementation cost
- Allow for expansion to larger intersections

Verification Plan

- Environment under which verification plan(s) were developed
- Methods and data to be used to verify compliance of each functional requirement
- Traffic demand scenarios for use to emulate
  - Demand likely satisfy D-CS stage 1 requirement
  - Demand likely exceeds D-CS stage 1 condition, but satisfies D-CS stage 2 condition
  - Demand exceeds D-CS stage 2 condition and would result in system max-out
- Prefer unified verification plan but can accept platform dependent verification plan

QUESTIONS?