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"TEXAS STAND ALONE ARTERIAL SYSTEMS"

Paper Based on Talk

Presented by

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at

TRB Annual Meeting  
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in Washington, D.C.

Updated by  
Jim Williams  
and

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1. Introduction

This paper involves the review of two traffic signal systems developed by the Texas Department of Highways and Public Transportation. Both systems involve the interconnection of NEMA full traffic actuated controllers. The two systems are the FACTS System - "Flexible Advanced Computer Traffic Signal" and the DARTS System - "Dynamic Artery Responsive Traffic Signal." These two systems provide a good solution where traffic pattern flexibility requires more patterns than presently provided by fixed time (pre-time) systems. The two systems also provide improved operations where multiphase traffic signal control is required at several intersections within a system. Fixed time systems are the basic systems installed by the Texas Department of Highways and Public Transportation and these systems operate very well. Less than five patterns are required where fixed time systems have been installed. The two systems to be discussed are not intended to replace fixed time systems but to round out the selection of systems available for solving traffic signal system problems.

2. DARTS System<sup>1</sup>

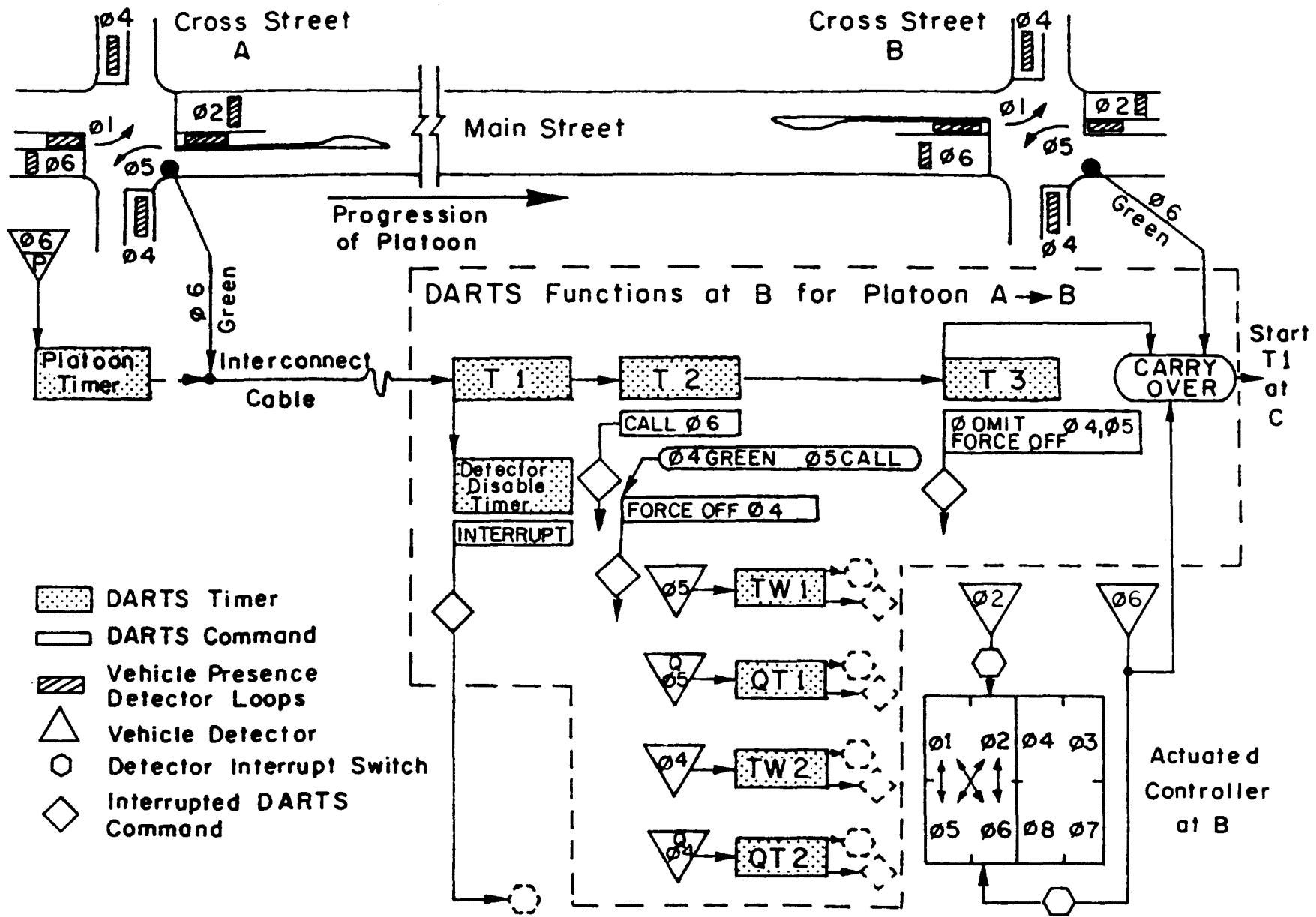
The DARTS System, which stands for Dynamic Artery Responsive Traffic Signal system, consists of a series of NEMA full actuated traffic signals each with an external logic modular Dynamic Coordination Unit. The system was developed by traffic signal personnel from the Department's San Antonio District.

The system permits each intersection to function in its normal isolated full actuated mode until a platoon (queue) is detected along the arterial at an intersection. Platoon coordination is achieved on an "intersection to intersection" basis. One system has been installed along SH 218 north of San Antonio and a second system is being installed along Ocean Drive in Corpus Christi.

a. Operation

The "intersection to intersection" type of coordination is achieved by the upstream intersection (Cross Street A) advising the adjacent intersection (Cross Street B) through a start message of the exact moment it releases its platoon. A "static" platoon is determined at Cross Street A (See Figure 1) by a line of cars backed during the red across a detector located a specified distance from the stop line (i.e., 4 cars per lane stopped during the red interval with the fourth car stopped over the detector located 75 feet from the stop line).

When a "static" platoon is released at Cross Street A, a Detector Disable Timer and a T-1 Timer are each started at Cross Street B. The Detector Disable Timer disables the Phase 2 and 6 arterial phase detectors (shown in Figure 1). This permits the cross street movement(s) and the Phase 1 left turn movement which conflicts with the direction of the platoon movement to occur. When the Detector Disable



2

FIGURE 1  
OPERATIONAL LAYOUT FOR DARTS SYSTEM

Timer times out, Phase 2 and Phase 6 vehicle demand is again received by the controller. Interval Timer T-1 continues to time at the end of the Detector Disable Timer interval. The purpose of Interval Timer T-1, which varies in length of time with the distance between intersections and speed of traffic, is to assure that Timer T-2 begins at the proper moment.

Interval Timer T-2 begins to time at the end of Interval T-1. If Phase 6 is already green at the beginning of the T-2 interval, the Phase 6 green will be maintained because the platoon has reached a point near Cross Street B prohibiting the time needed for the controller to move from Phase 6 to the conflicting phase(s) and return to Phase 6 before the platoon arrives. If the coordination unit recognizes a Phase 5 vehicle demand and is in Phase 4 at the beginning of Interval T-2, the controller will be forced to service Phase 5 at that time. If the controller is already servicing Phase 5 or if Phase 4 minimum green has not been satisfied, the Cross Street B controller unit will not be affected.

Interval Timer T-3 begins to time at the end of Interval T-2. If the controller is not in Phase 6 at the beginning of Interval T-3, the coordination unit forces Phase 5 to end at the end of its minimum green time. If the controller is in Phase 4, the coordination unit forces Phase 4 to end at the end of its minimum green time and causes Phase 5 to be omitted (if a call has been placed for Phase 5). The coordination unit also dispatches a start message signal to Cross Street C that a "carry over" platoon has started at Cross Street B and allows the Detector Disable Timer and Timer T-1 to be started at Cross Street C.

Platoons can be generated at any intersection and sent through the rest of the system. However, if a platoon is already in route, the platoon start output is withheld until the two platoons can be compressed into one. For example, if a platoon has been recognized at Cross Street A and has been dispatched to Cross Street B, a "static" platoon recognized at Cross Street B will not preempt a platoon start message for Cross Street C until the platoon from Cross Street A is near arrival at Cross Street B. When the "static" platoon is recognized as waiting during the Phase 6 main street red at Cross Street B, the Coordination Unit will adjust the force-to commands from Interval T-3 back into Interval T-2. This feature allows the "static" platoon at Cross Street B to move forward in proper relation with the oncoming Cross Street A "carry over" platoon so that the "carry over" platoon does not need to slow down or stop.

When the T-3 Interval times out, all commands at Cross Street B are released and the controller unit is free to gap out Phase 6 at the platoon's end.

For progression in the opposite direction, each coordination unit provides a duplicate of the above for that direction.

There may be times of the day when the artery itself will experience excessive stacking between signalized intersections, caused either by arterial coordination inhibits or either simply exceptionally large peak arterial volumes. If the intersections are closely spaced, there will then exist a definite need to have simultaneous arterial greens between the two signalized intersections where excessive "static platoon" arterial stacking is occurring. Once the artery traffic has stacked back far enough to show continued presence over midblock sampling loops

for a minimum period of time, the coordination unit will immediately institute phase skips to revert to artery phase green, thereby clearing the "static platoon" traffic prior to the arrival of the upstream "carry over" platoon. This is one application of the manner in which a "static" platoon at Cross Street B is started in relation to the oncoming platoon from Cross Street A.

Each coordination unit has two methods for each of Phases 4 and 5 inhibiting the coordination unit operation. The first involves time waiting. When one or more vehicles on Phases 4 or 5 have been waiting for more than a preset time, the coordination unit operation is inhibited. At the same time the detectors for Phases 2 and 6 are disabled. The second method involves a platoon inhibit. A second detector is placed in advance of the stop line of the approaches for Phases 4 and 5. When vehicles stack back over this detector, the coordination unit operation is inhibited and the detectors for Phases 2 and 6 are disabled. Upon termination of the phase which caused the coordination unit to be inhibited, the coordination unit commands are again activated.

The DARTS equipment described has been built by one manufacturer and specifications are available. The specification for an expanded version of DARTS has just been completed. There are two additional timers to handle pedestrian movements. This unit has not been built yet.

#### b. Systems

There are two systems which utilize the equipment described. The first involves a 12 multiphase full actuated traffic signal system located along a 3.4 mile section of SH 218 in Universal City north of San Antonio (shown in Figure 2). SH 218 is a five lane arterial which carries between 20,500 vpd and 26,000 vpd with an average of approximately 23,000 vpd. Travel time runs show that with the DARTS System the average speed for peak and off peak traffic has increased from 29 mph to 34 mph and that the number of stops has been reduced from an average of 3.9 to 0.8 in each direction. During the off peak periods, the average speed increased from 29 mph to 35 mph with a reduction of stops from 4.0 to 0.7. The average of the posted speed limits along SH 218 is 39 mph.

The cost for installing the control equipment and interconnect cable by State forces for the SH 218 system was \$150,000 with the DARTS Coordination Unit costing \$3,000 per intersection (\$3,500 installed).

The second system involves four intersections along Ocean Drive (shown in Figure 3) in Corpus Christi. This system consists of four intersections located along a 5,500 foot section of Ocean Drive approximately one mile from the Central Business District. Ocean Drive is a four lane facility with channelized left turn lanes. Traffic volumes within the project length vary from 12,500 vpd to 31,000 vpd with an average of 23,500 vpd along Ocean Drive. Cross street volumes range from 1,400 vpd to 4,600 vpd. The cost for the installation of new controllers (including the coordination units), detectors, and interconnect cable by city forces is estimated to be \$70,000. The project has been completed, but city forces have not finished fine-tuning the system and no evaluation has been made yet.

The SH 218 project shows that the DARTS System provides benefits in coordinating isolated full actuated controllers at a reasonable cost.

### 3. FACTS System<sup>2</sup>

The FACTS System has been developed jointly by the Department's Traffic Engineering and Computer Operations personnel in the Central Office in Austin. The system implements the results of research conducted by Texas Transportation

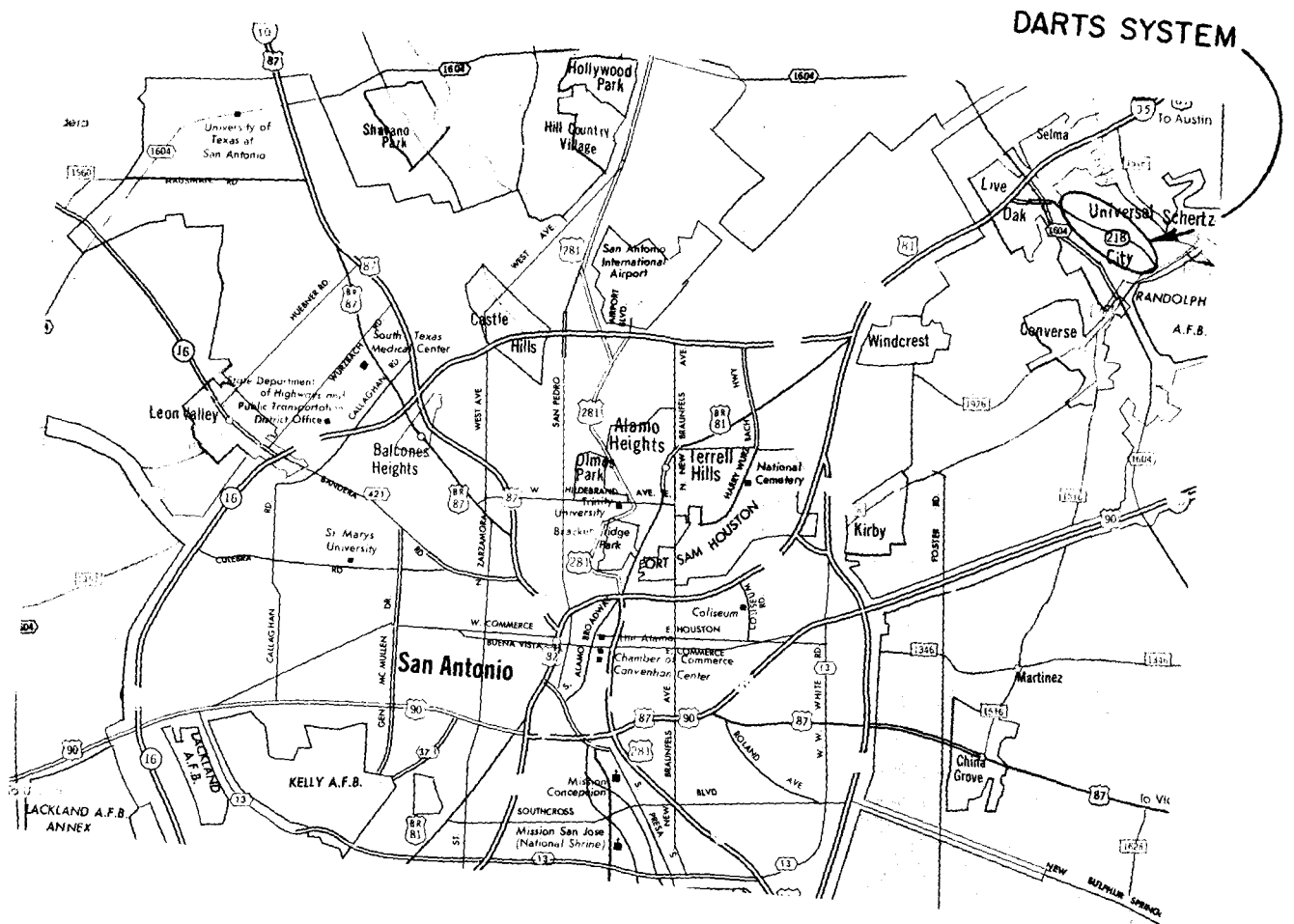


FIGURE 2  
 DARTS SYSTEM  
 SH 218 in Universal City

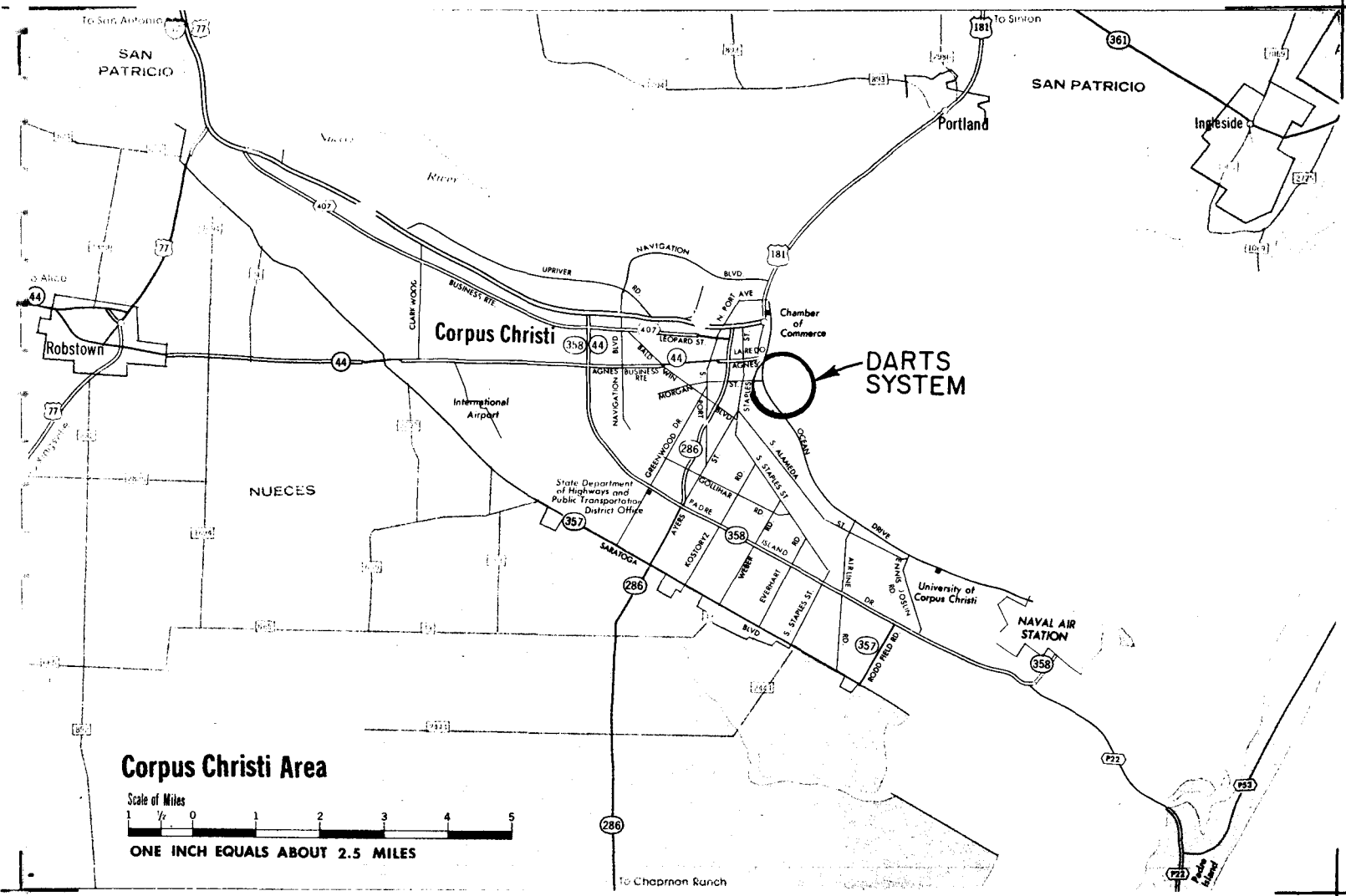


FIGURE 3  
**DARTS SYSTEM**  
 Ocean Drive in Corpus Christi

Institute along the US 75 (North Central Expressway) Corridor in Dallas together with algorithms obtained from many years of observation and experience by the Department's Traffic Engineering personnel.

The FACTS System is one software module of a total traffic management software library which will provide for freeway control and surveillance, frontage road progression, arterial street progression, and freeway corridor grid street operation.

Essentially, the FACTS System consists of the interconnection of NEMA full actuated and/or solid state fixed time traffic signals with a digital mini-computer to provide arterial street, grid street system, and freeway frontage road control. The present design provides control of up to six subsystems. The system has been installed along NASA 1 in front of the Lyndon B. Johnson Space Center (NASA) and along SH 225 in Deer Park as shown in Figure 4. The system is also being installed along two major arterials which cross IH 30 in Fort Worth (shown in Figure 5) and plans are developing to install the system along two major intersecting arterials north of Houston. Another system is planned in Corpus Christi that will involve a combination of fixed-time and full-actuated signals on two intersecting arterials. Further, the variable sequence and progression control features of the system design are included in a standard Eagle Signal Comtran System being installed in College Station, Texas. The College Station project involves 14 intersections located along four arterials which encompass the Texas A&M University campus. The College Station system is expansible to 50 multiphase intersections within eight subsystems.

The FACTS System is flexible in that it is being used to control frontage road intersections along SH 225 and arterial street intersections along the remaining systems mentioned. The system provides three basic needs:

- (1) The capability of providing optimum progression,
- (2) The capability of distributing traffic onto the cross streets and businesses along a route, and
- (3) The ability to provide optimum time for all intersection movements including cross street and left turn movements.

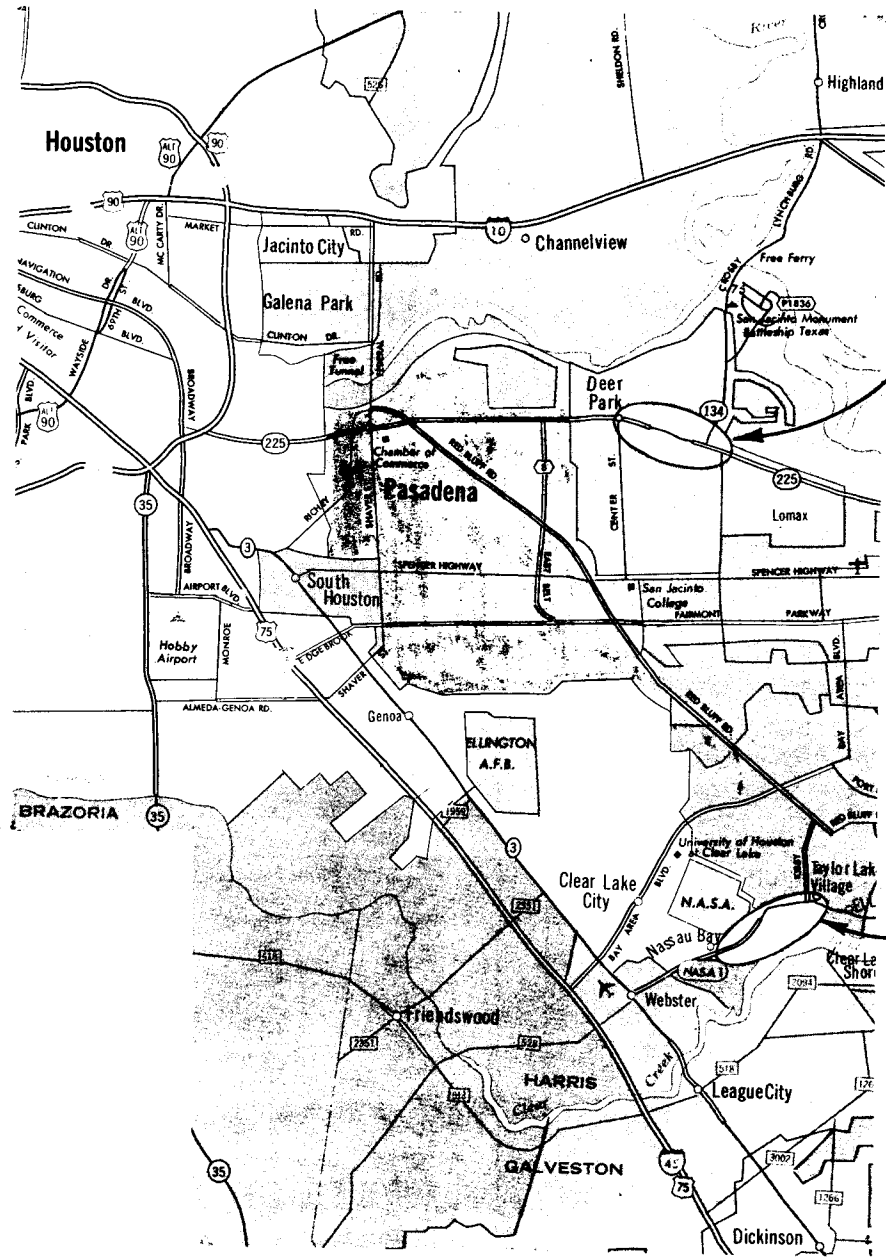
One of the aims of the arterial street and frontage road system is to provide the capability for implementing traffic patterns generated off line by the PASSER II and PASSER III progression programs during interconnected operation.

The SH 225 and NASA 1 systems provide continuous diagnostics of the sampling detectors, intersection controllers and "failed open" (no vehicle calls) position for each intersection detector. Although the two systems are stand alone in design, all sampling detector traffic count data, computer traffic control data, and tables in storage are monitored from the District traffic signal shop and from the District office in Houston. CRTs and teletypewriters are located at these two offices with dialup communications to each site. This feature has saved many hours of travel time to the sites, in troubleshooting from the maintenance shop, and in making traffic counts.

#### a. Interconnected Operation

The system has the capability of selecting and implementing up to 188 different patterns for each of six subsystems. A pattern consists of the related cycle length, offset, split and phase sequence. The patterns can be selected by traffic demand (traffic responsive), time of day, or manual modes. The capability of 188 different patterns gives the user virtually unlimited flexibility. However, the amount of information that can be stored in the data base is dependent on the core size of the computer and the complexity of the system. The computers that have been used on these systems have a core size of 24K (16 byte words), and are





FACTS SYSTEM

FACTS SYSTEM

FIGURE 4  
**FACTS SYSTEM**  
 NASA I in Harris County  
 and SH225 in Deer Park

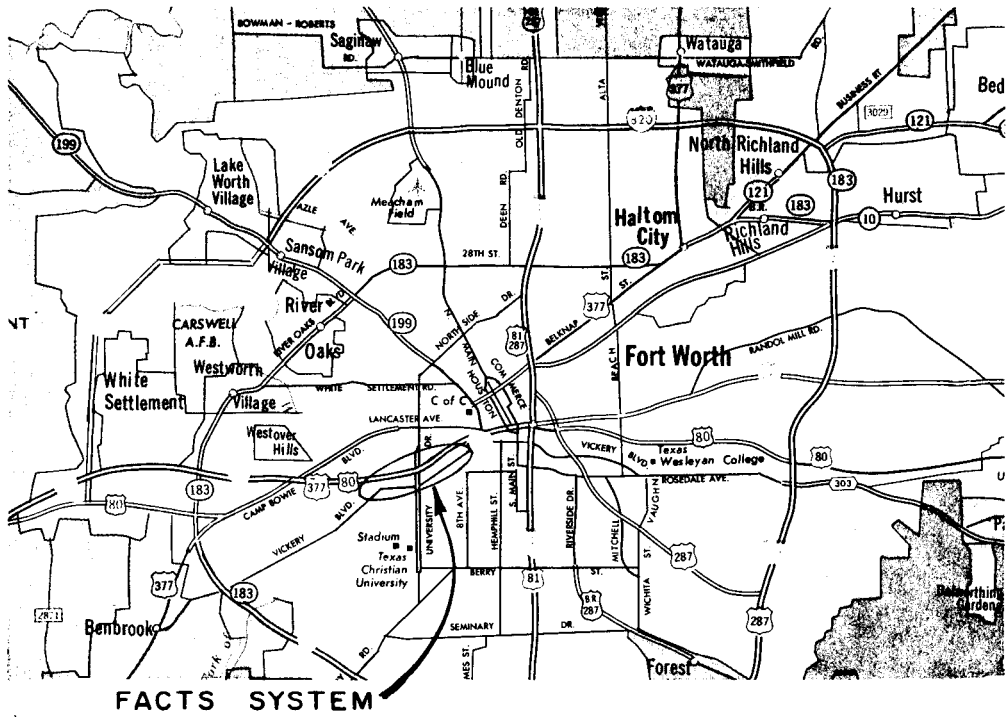


FIGURE 5  
 FACTS SYSTEM  
 IH30 in Fort Worth

expandable to 32K. The basic software program is the same for all systems. Only the user supplied data base varies, depending on the system size (the number of subsystems, intersections, and detectors). The amount of core used by each portion of the software on the SH 225 system is shown on Table 1. A pattern is selected as follows under traffic responsive control:

- (1) Cycle length is determined from Volume plus Occupancy data received from selected detectors. The phase sequence for each multiphase intersection is associated with the cycle length.
- (2) Offset is chosen after the cycle length is chosen. The offset is based on Volume plus Occupancy data obtained from a selected set of detectors which can differ from those used for the cycle length selection.
- (3) Split is chosen after the cycle length-offset combination is determined. A set of detectors can be chosen for split selection which differ from those used in cycle length and offset selection.

The system uses a combination of the two most recent three-minute sampling periods. Cycle length and offset can be changed at the end of the two most recent sampling periods and split can be changed at the end of each sampling period. Two three-minute sampling periods have been found to work well.

Although the system uses traffic patterns and time space progression bands in controlling the arterial traffic flow, it does not operate as a fixed-time system when full actuated controllers are utilized. The system allows actuated control phases to be skipped, shortened and/or gapped out by the local option intersection detectors. The ability to skip, shorten, and gap out phases during computer control is, however, restricted in each traffic pattern on how the progression band is set up. The option of allowing phases to be skipped, shortened and gapped out can be varied for each phase from pattern to pattern. Properly designed traffic patterns will allow the progression band to increase when cross street and arterial left turns can be skipped, shortened or gapped out under computer supervision. Cross street and/or left turn phase movements are not permitted to be skipped, shortened, or gapped out for a pattern if no benefit is gained on the main street movement.

The major features of the system are listed below. Most of these features are not available in conventional traffic responsive systems.

(1) Multiple Splits - Multiple splits can be assigned to each cycle length-offset combination (i.e., 80 second cycle length-inbound offset combination). Up to four separate splits are available for each of two light-traffic cycle length-offset combinations and up to six separate splits are available for each of 30 additional heavier traffic cycle length-offset combinations. The 30 cycle length-offset combinations consist of 12 cycle lengths with each cycle length associated with an average offset value, 9 cycle lengths with each associated with an inbound offset value, and 9 cycle lengths with each associated with an outbound offset value. The cycle length-offset combinations coupled with the gap out phase shortening, and phase skipping features provide an infinite number of split patterns. Each of the above-mentioned intersection splits has a unique intersection offset value assigned to it. This assures that the offset will occur at the optimum moment at each intersection during each pattern.

A total of 188 cycle-offset-split pattern combinations are available for each subsystem. This does not mean that all patterns need to be used. It does mean that a considerable amount of flexibility is available when needed (i.e., during the peak periods). The basic number of patterns (188) are increased through the use of the full actuated controllers.

TABLE 1

Core Usage for SH225  
Arterial Traffic Control Computer System

Total Routines and Program Data Base = 12,927

* {	Supervisor	=	2,653
	Program Data Base	=	1,977
	Traffic Programs	=	7,413
	Input/Output Tables	=	<u>884</u>
			<u>12,927</u>

User Data Base = 9,793

Total Core Used = 22,720

Core Per Intersection = 640

Core Per Subsystem = 457

Core Per Detector = 87

Core Per Register = 18

Core Per Global Tables = 851

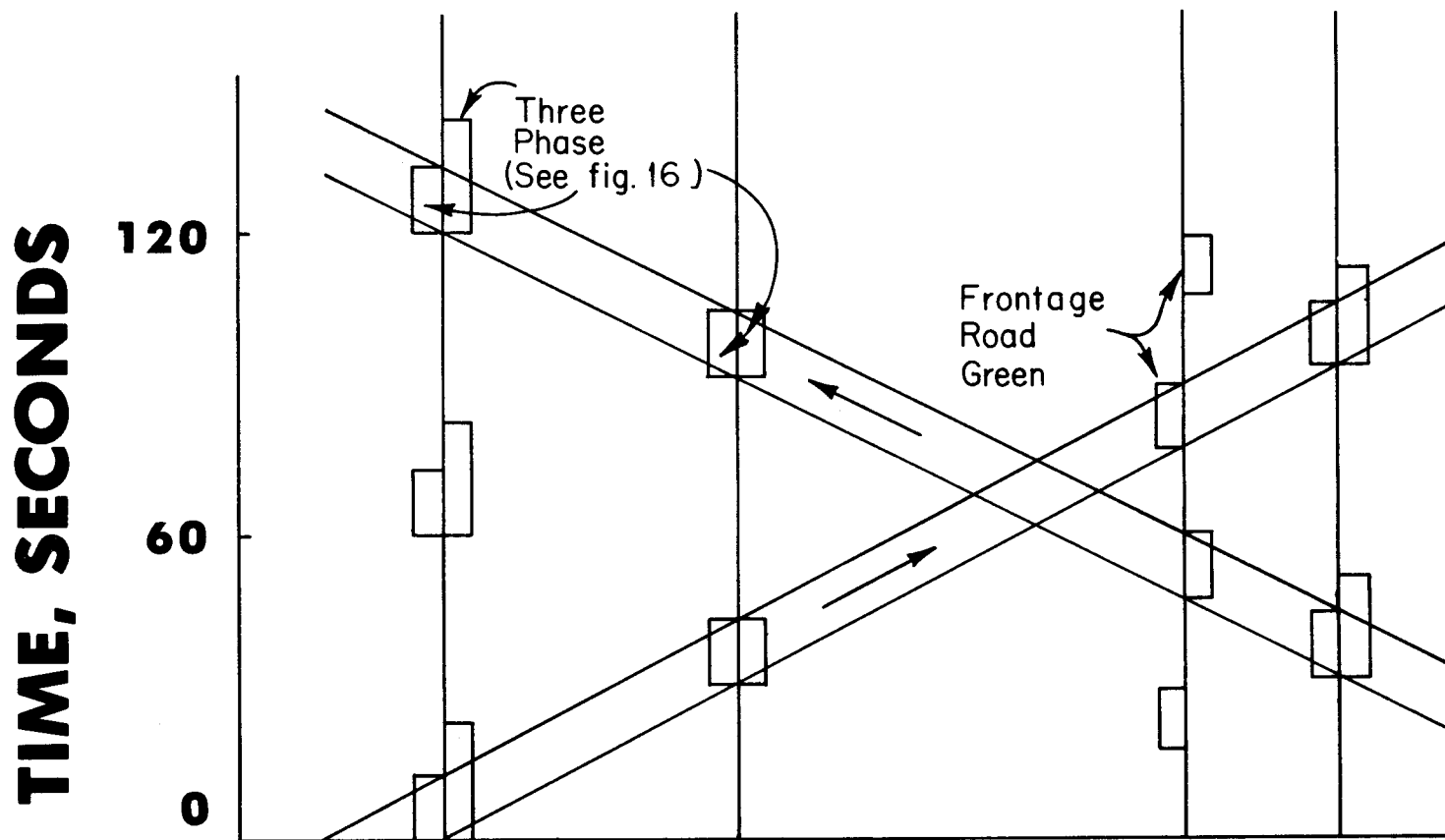
Total Core Available with 24K = 24,477

Core Used = 22,720

Core Unused = 1,757

\* BASIC SOFTWARE PROGRAM  
COMMON TO ALL SYSTEMS.

FIGURE 6  
VARIABLE SEQUENCE



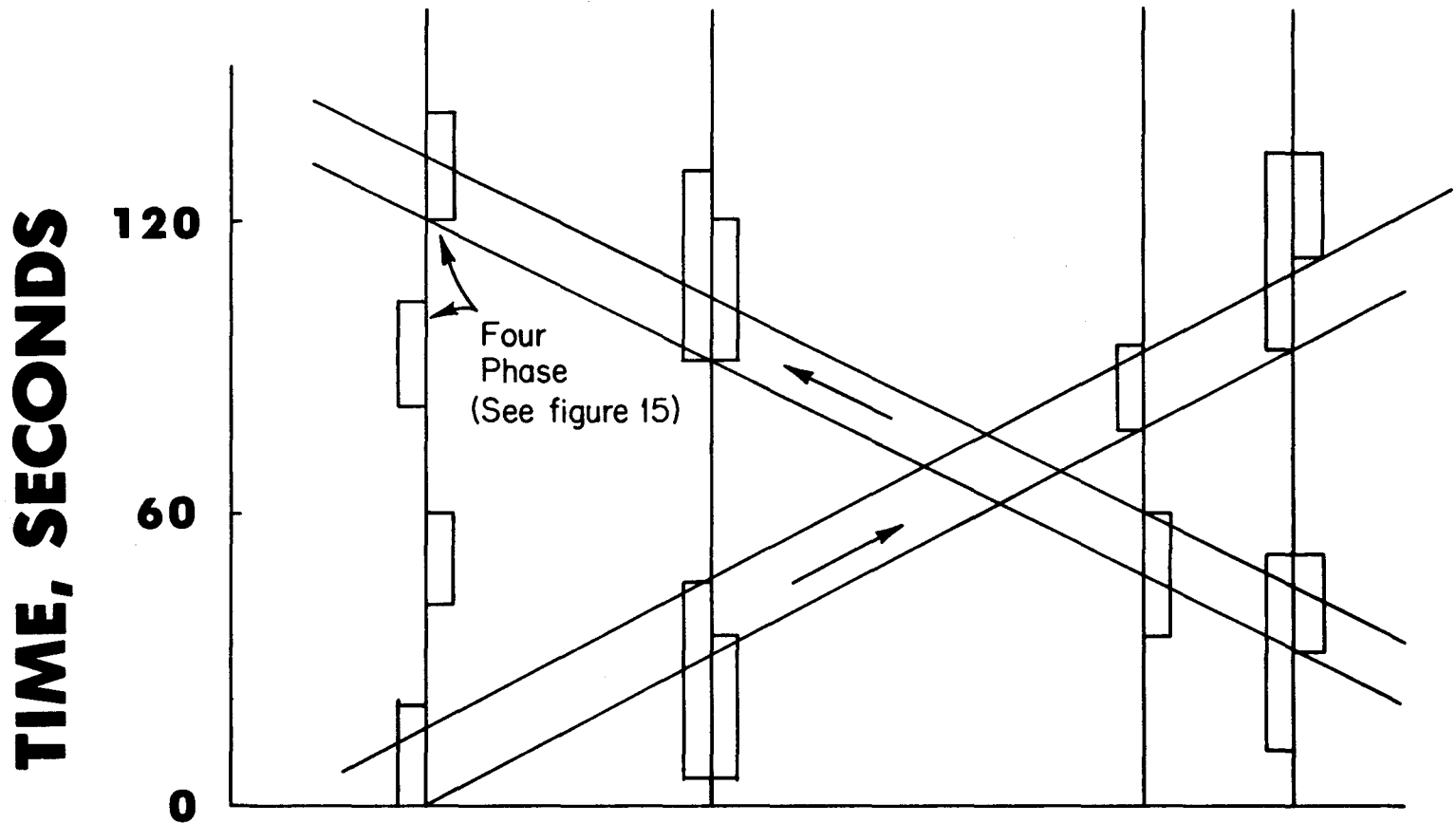
**INTERCHANGE LOCATION**

**60 SEC. CYCLE**

**FRONTAGE ROAD PROGRESSION**

FIGURE 7

# VARIABLE SEQUENCE



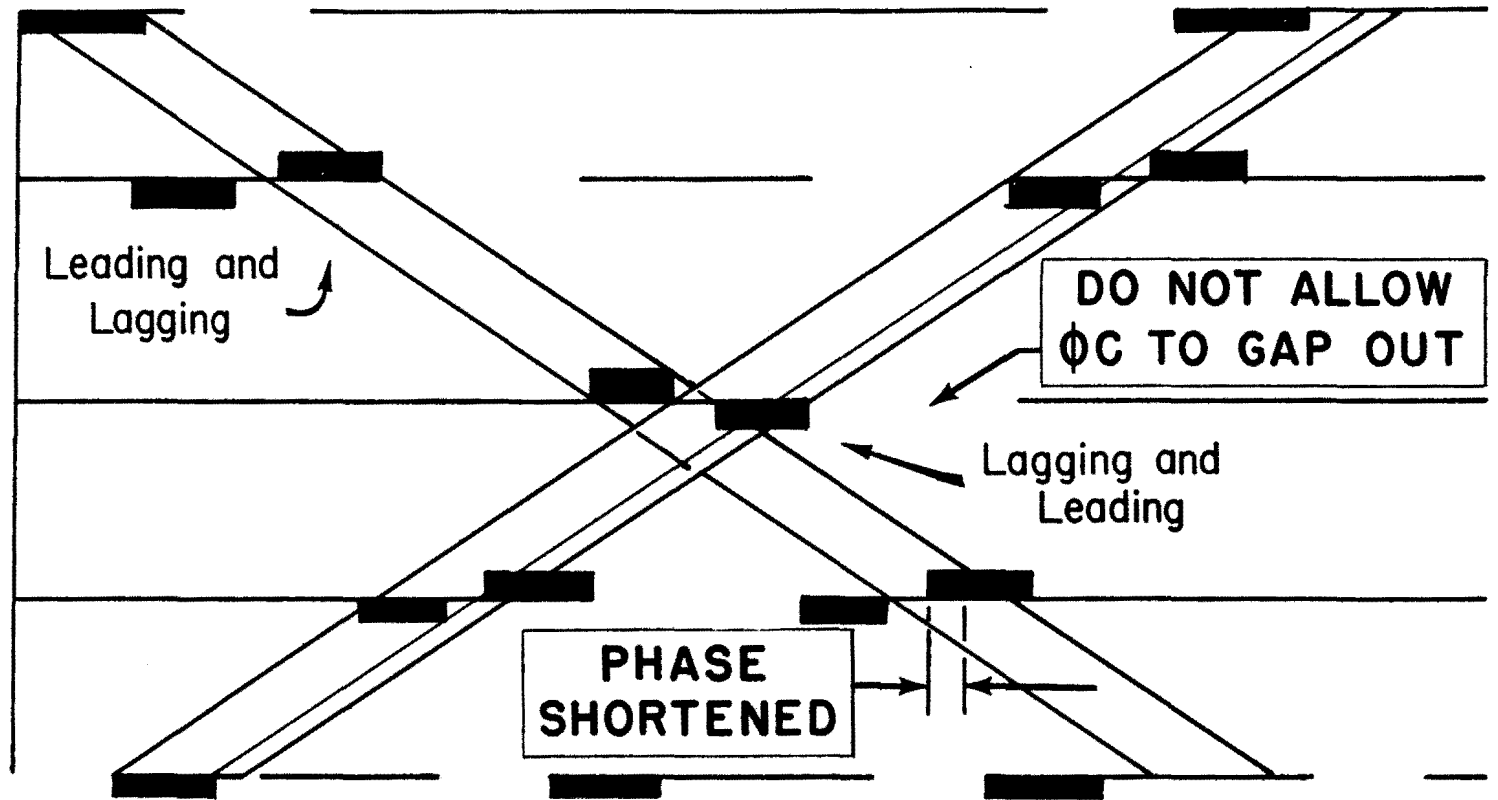
## INTERCHANGE LOCATION

80 SEC. CYCLE

FRONTAGE ROAD PROGRESSION

FIGURE 8

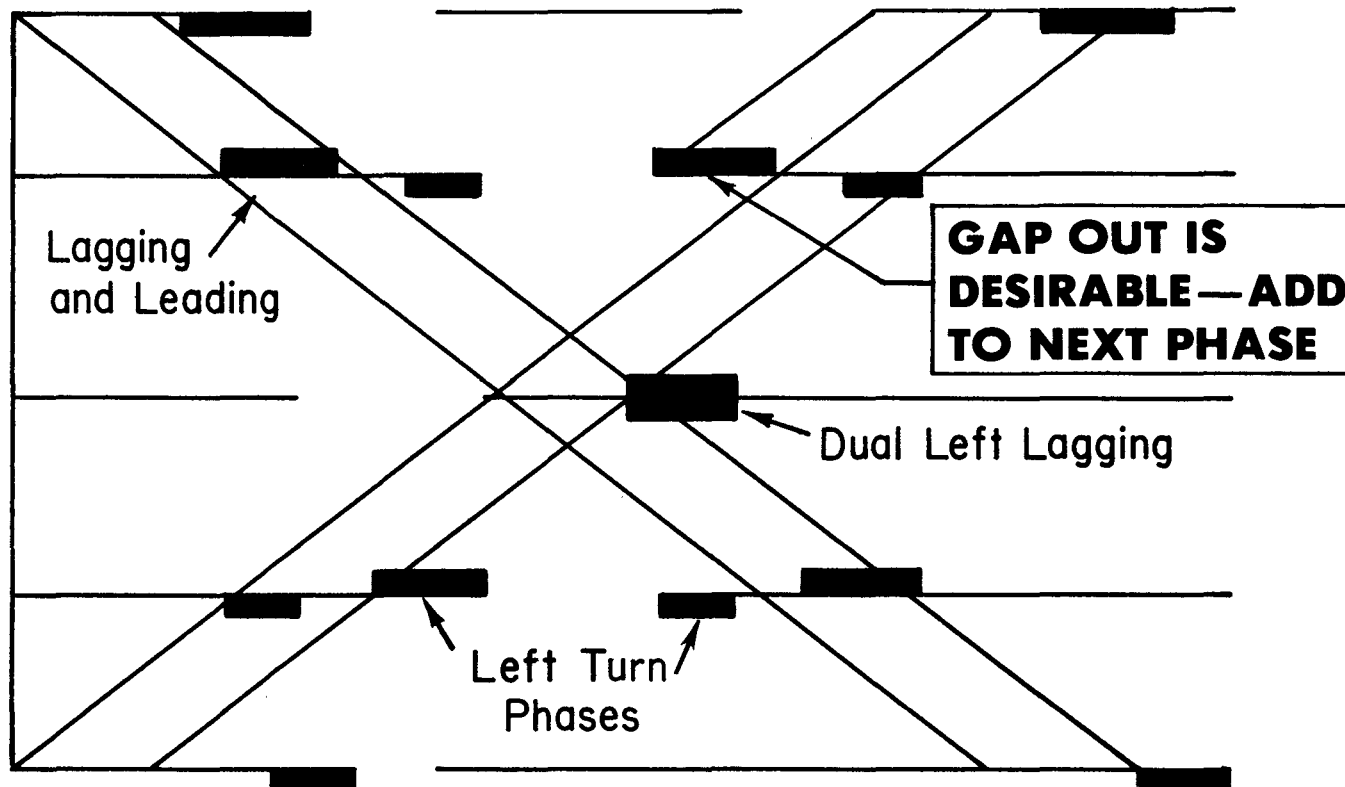
# VARIABLE SEQUENCE AND LOCAL OPTIONS



**AVERAGE OFFSET  
FOR 65 SECOND CYCLE  
ARTERIAL STREET PROGRESSION**

FIGURE 9

# VARIABLE SEQUENCE AND LOCAL OPTIONS



**AVERAGE OFFSET  
FOR 70 & 75 SECOND CYCLES  
ARTERIAL STREET PROGRESSION**



(2) Variable Subsystem Sequence Pattern Implementation - This feature allows each intersection to have different phase sequences for different subsystem traffic patterns (i.e., an intersection's phase sequence-dual left turns first, straight throughs first, leading/lagging green, or lagging/leading green may vary from pattern to pattern). The phase sequence is changed in order to obtain optimum progression during each cycle length. The cross street sequences may also vary from one pattern to another. Changing the pattern sequence along both the arterial street and the cross street is important where progression is being provided along two intersecting arterials. The changes in pattern sequences as called for by the system detectors are provided by software within the computer. The change in phase sequence is shown in Figures 6-9.

(3) Local Intersection Control Options - The traffic engineer has the ability to allow phase shortening, skipping and gapping out options at each intersection through the combination of the intersection detectors and computer software (see Figures 8 and 9). Those options can be different from one subsystem pattern to another.

(4) Floating Offset Points and Background Cycle Timers - When transitioning from one subsystem pattern to another, the computer sets the background cycle timer to the value of the offset of the new pattern for the intersection that first times out its cycle. The remaining intersections begin implementing offsets as soon as they reach the end of their cycle. This enables the system to change patterns more rapidly than if the same reference point were always used.

(5) Offset Correction During Pattern Transition - The conventional techniques for correcting offsets during pattern transition has been expanded to provide a smoother transition. The time required to correct the offset is either added to or subtracted from the time provided by the phase green intervals by the new pattern being implemented. Transition times are either added or subtracted, depending on whether the offset to be corrected is more than or less than a predetermined variable, generally 50 or 70% of the cycle.

The FACTS System offset correction allows each pattern to transition differently. This allows the user to transition some patterns more rapidly than others; for example, a pattern designed to handle a sudden peak surge of traffic can be made to normally transition in one cycle, while other patterns during normal traffic can be made to transition slower with less traffic disruption.

(6) Surfing - Although cycle lengths and offsets can be changed only after the first two sampling periods or at the end of each sampling period thereafter, it is possible to stay ahead of increasing traffic demand by providing a cycle length somewhat longer (i.e., 10-15% longer) than the optimum cycle length.

(7) Maintenance Calls - An addition to the system will allow the computer to be interrogated by telephone from a remote location to determine if any detectors, controllers or the computer are not functioning properly. Further, the computer automatically carries out a series of diagnostics at each intersection.

(8) Subsystem Locking - The various cycle length-offset level-split combinations are selected separately for each subsystem. When the difference in cycle lengths of adjacent subsystems is within a preset value, the two subsystems will be locked together at the higher cycle length and phase pattern. When the subsystems again require cycle lengths that are **not** within the preset value of each other, they will operate independently. For example, if the locking factor is set at 10 seconds, and cycle lengths of 70 and 80 seconds are selected for two adjacent subsystems, they will be locked together on the 80 second pattern.

(9) Full Computer Control - The computer supervises each intersection phase through the hold, phase omit, and force off capabilities of the NEMA controllers. The adherence to the minimum green and clearance interval times set on each controller along with the conflict monitor assure a fail-safe intersection operation.

b. Full Traffic Actuated Operation

When a subsystem utilizes full traffic actuated signals and the computer calls for subsystem full traffic actuated control, the controllers within the subsystem will operate independently of each other.

The subsystem controllers will operate in isolated full traffic actuated control: (1) when the volume and occupancy parameters for determining cycle lengths fall below or above predetermined threshold values (as might occur upstream or downstream of an accident), (2) when called for by time of day, (3) when called for manually, or (4) when necessitated by an interruption of communications which will require maintenance. Progression can be maintained at the intersections in adjacent subsystems during the time the controllers within the subsystem are operating under isolated full actuated control.

Once the full traffic actuated control mode occurs, it will remain in effect for a predetermined minimum period of time. At the end of the minimum period, the computer will call either for continued full traffic actuated control or for a return to interconnected operation for the applicable intersections.

c. Systems

Of the systems mentioned previously, two are in operation at present--the NASA 1 system and the SH 225 system. The SH 225 system went into operation on October 30, 1980. The NASA 1 system has been in operation since September 1979. The following describes these two systems:

(1) NASA 1 System. The NASA 1 system is an arterial system consisting of six intersections located within a 5,370 foot distance (see Figure 10). NASA 1 is a four and six lane divided arterial with channelized left turn lanes which carries between 40,000 and 75,000 vpd (average of 55,000 vpd) with cross street volumes of 4,500 to 14,500 vpd. Cycle lengths vary from 65 seconds to 130 seconds.

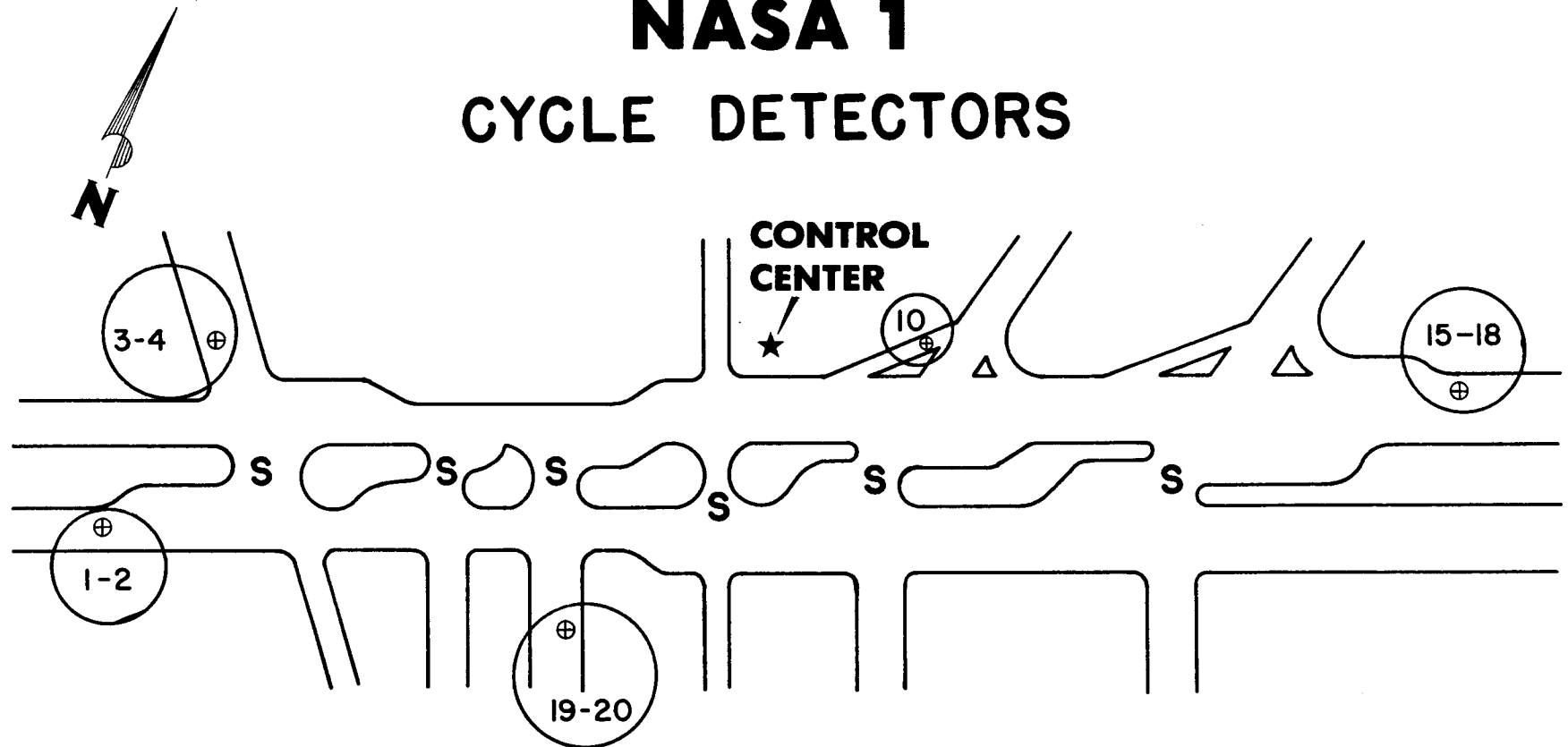
The facility serves many traffic generators. They include NASA, two professional office complexes, apartments, commercial strip development, and a large residential area. Parallel routes are not available as alternates to NASA 1.

The computer controller system was installed for \$287,000. This cost included the installation of two new intersections and the modernization and rewiring of two intersections, replacement of NEMA controllers at four intersections, and installation of a digital computer and interconnect cable. Three of the controllers are eight phase, two are three phase, and one is two phase by contract. The controllers are all expandible to provide eight phase operation. The sampling detectors for cycle length, offset and split selection are shown in Figures 10-12.

An evaluation of the six intersection computerized signal system and comparison of it to the original isolated full actuated control operation was undertaken in December 1979 by Houston District and Austin office (Central Office) personnel. The techniques employed for this evaluation were an FHWA approved intersection delay study and a speed and delay study. The delay study measured duration of vehicle stops on ten of the twenty-one intersection approaches. The ten approaches chosen represented the system improvement conservatively.

FIGURE 10

# NASA 1 CYCLE DETECTORS



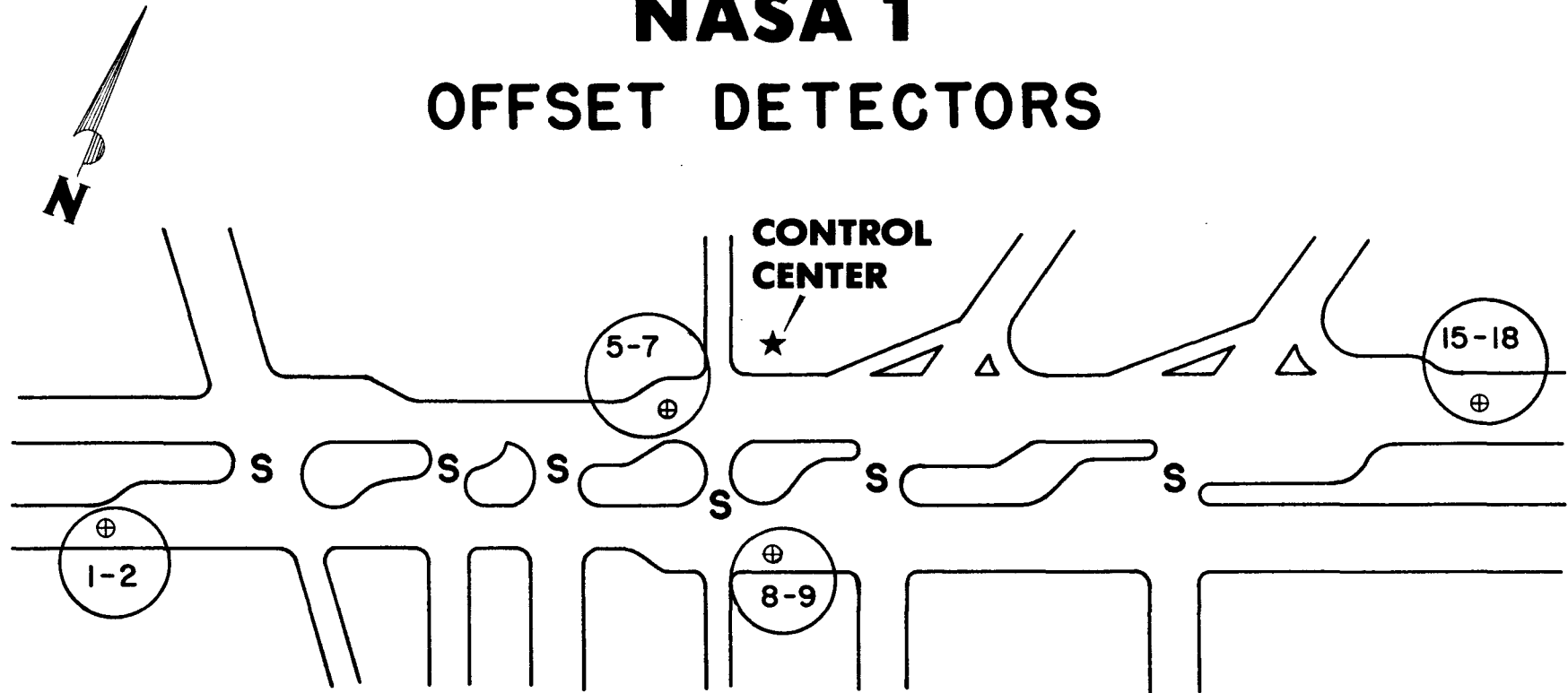
18

## LEGEND

- ⊕ SYSTEM DETECTORS
- 3-4 - DETECTOR NUMBER
- S-SIGNALIZED INTERSECTION

FIGURE 11

# NASA 1 OFFSET DETECTORS



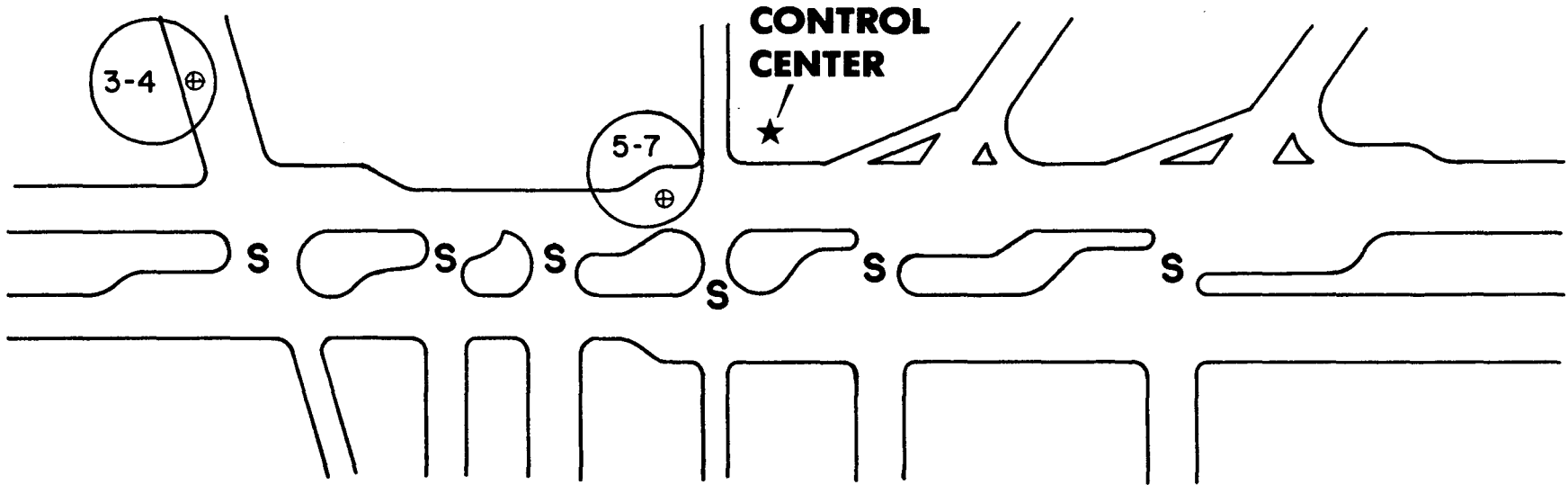
## LEGEND

- ⊕ SYSTEM DETECTORS
- 5-7- DETECTOR NUMBER
- S- SIGNALIZED INTERSECTION

FIGURE 12

# NASA 1

## SPLIT DETECTORS



### LEGEND

- ⊕ SYSTEM DETECTORS
- 5-7 - DETECTOR NUMBER
- S-SIGNALIZED INTERSECTION

The studies show a savings of 321 hours of delay each day. There was a 9.4 mph increase in average speed over the original 25 mph operation. This represents a thirty-eight percent (38%) improvement in both delay and speed. Stops were reduced from 1.56 to 1.05 per run which resulted in a 33% reduction. The resulting fuel and delay savings based on a 12-hour day, five days per week are \$389,000 per year. This particular system has a 13.5 benefit to cost ratio based on a ten-year period. Its present worth by standard economics procedure is \$2,170,000.

(2) SH 225. The system is located along a freeway facility along which the main lanes have not been constructed. Traffic is carried along what will eventually become the two frontage roads. The two frontage roads are separated by a median width of 145 feet for part of the distance and 315 feet for the remainder. The traffic signals at the two frontage road intersections with a cross street will be defined as an "interchange." The system consists of six signalized interchanges located within a 2.72 mile distance. As is shown in Figure 13, a railroad track runs parallel to SH 225.

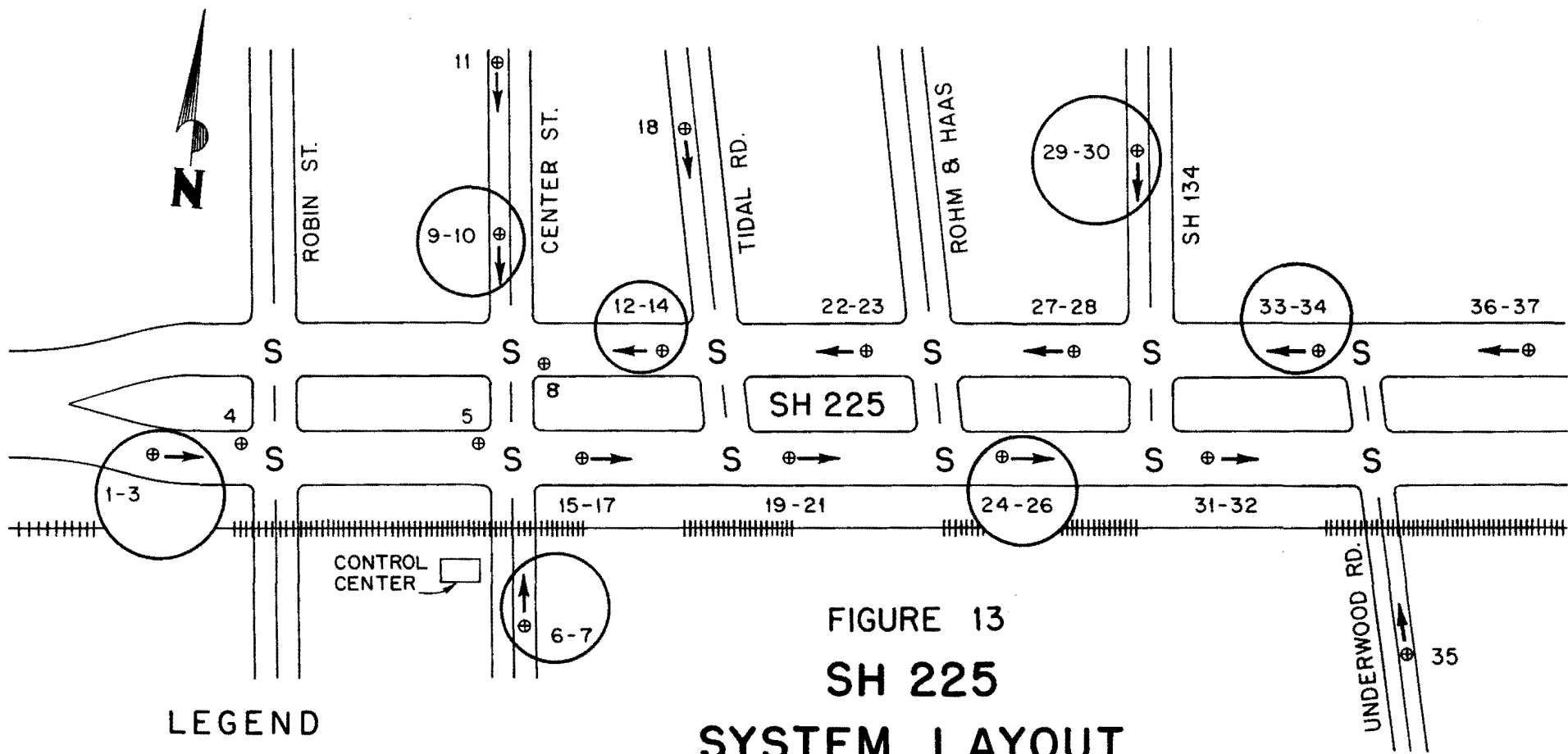
Petrochemical refineries are located along the north side of the traffic control system. Since these plants are bounded on the north by the Houston Ship Channel and since there are no alternate routes in the area, all traffic going to and from the plants must use SH 225. The plants operate on a three shift 24-hour basis. The cities of Deer Park and Lomax are located to the south of SH 225 and traffic from these cities also use SH 225 during the peak periods. Both frontage roads have three lanes for a portion of the distance and two lanes for the remainder of the length. SH 225 carries between 28,000 and 39,000 vehicles per day with an average of 33,000 vpd and the cross street traffic varies from 7,500 vpd and 13,000 vpd.

Each interchange controller consists of a standard NEMA full actuated dispatcher provided with a special microprocessor software design within the interchange controller which permits the phasings shown in Figures 15-17 during full actuated control. In addition, it is possible for the computer to control each of the three phases at one frontage road intersection independently of the three phases at the second frontage road intersection as shown in Figure 18. This is carried out through the use of the force off, hold, and phase omit features of the NEMA controller and the special microprocessor software. This capability permits the computer to provide any practical combination of phases at the two frontage road intersections. At intersections with railroad crossings, the traffic signals for the north frontage road continue to provide stop and go operation while those for the south frontage road are operated in the flashing mode during railroad preemption operations.

It may also be of interest to note that during isolated full actuated control, the controller can automatically change from the phasing shown in Figure 15 to the phasing shown in Figure 16 by time clock or other external command. The control operation described is available at present from one manufacturer and phase diagrams and specifications are available.

The sampling detector being used for selecting cycle lengths and offsets is shown in Figures 13-14. The split detectors have not been chosen to date.

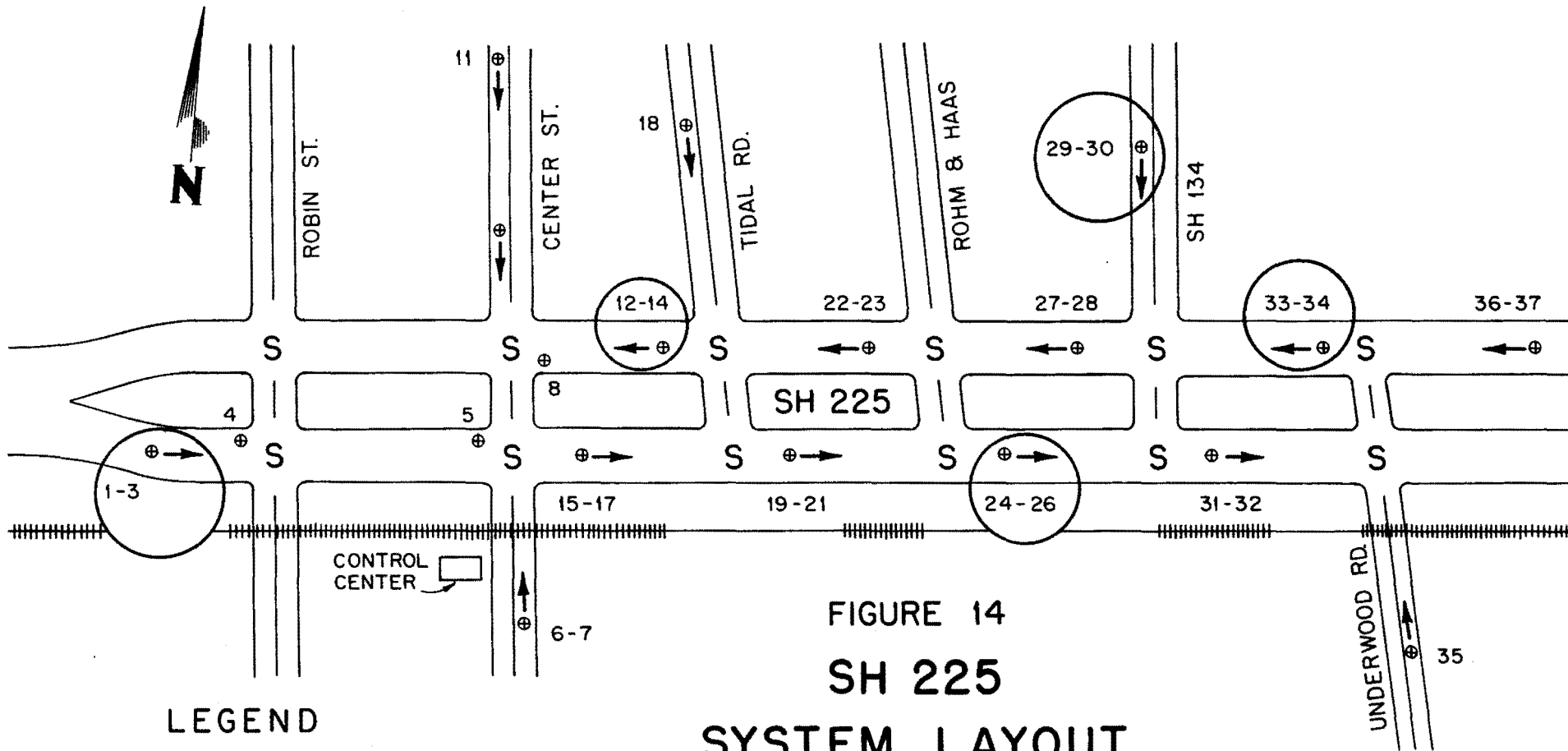
Cycle lengths being used at present vary between 65 seconds and 150 seconds. Since the system has been in operation for only a short time, we do not yet have any before and after data. The procedure used to prepare the data for the SH 225 system is described in Attachment A. It is provided as an example of the information and techniques necessary for the data preparation.



LEGEND

- ⊕ SYSTEM DETECTORS
- DIRECTION OF TRAVEL
- S SIGNALIZED INTERSECTION

FIGURE 13  
 SH 225  
 SYSTEM LAYOUT  
 DETECTORS FOR  
 CYCLE LENGTH SELECTION



LEGEND

- ⊕ SYSTEM DETECTORS
- DIRECTION OF TRAVEL
- S SIGNALIZED INTERSECTION

FIGURE 14  
 SH 225  
 SYSTEM LAYOUT  
 DETECTORS FOR  
 OFFSET SELECTION



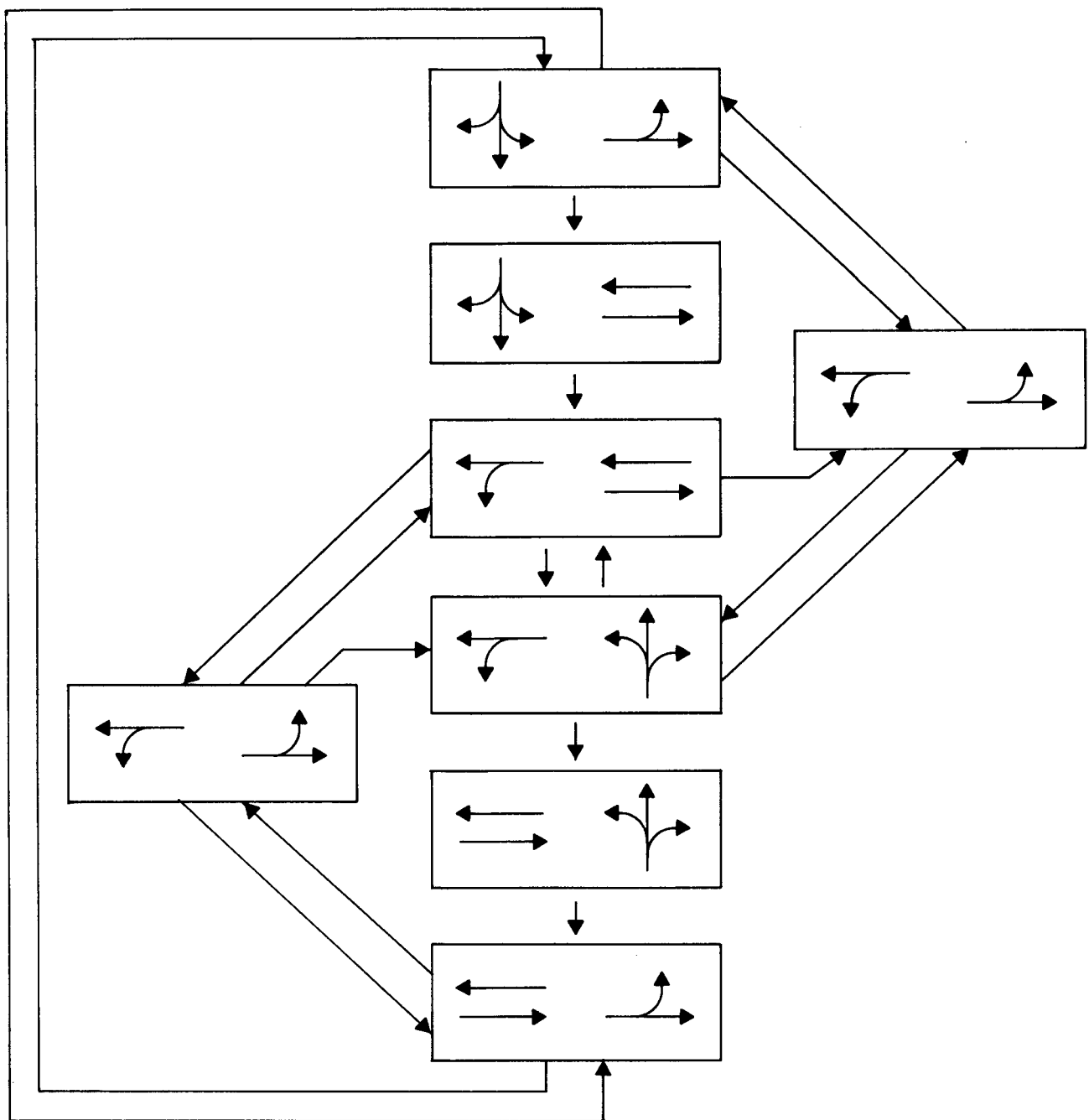


FIGURE 15

**FOUR PHASE  
FULL TRAFFIC ACTUATED  
DIAMOND INTERCHANGE OPERATION**

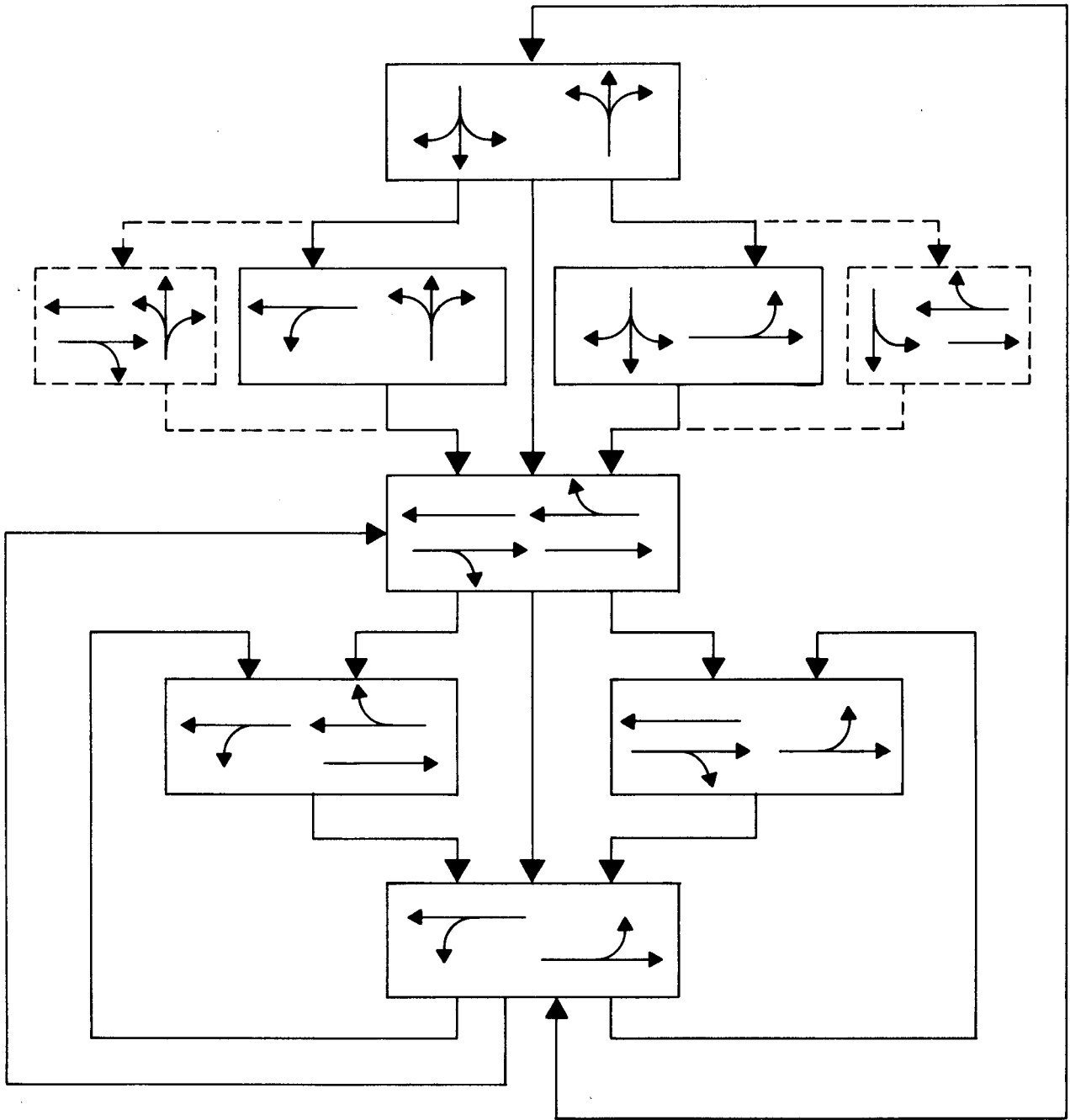


FIGURE 16

**THREE PHASE  
FULL TRAFFIC ACTUATED  
DIAMOND INTERCHANGE OPERATION**

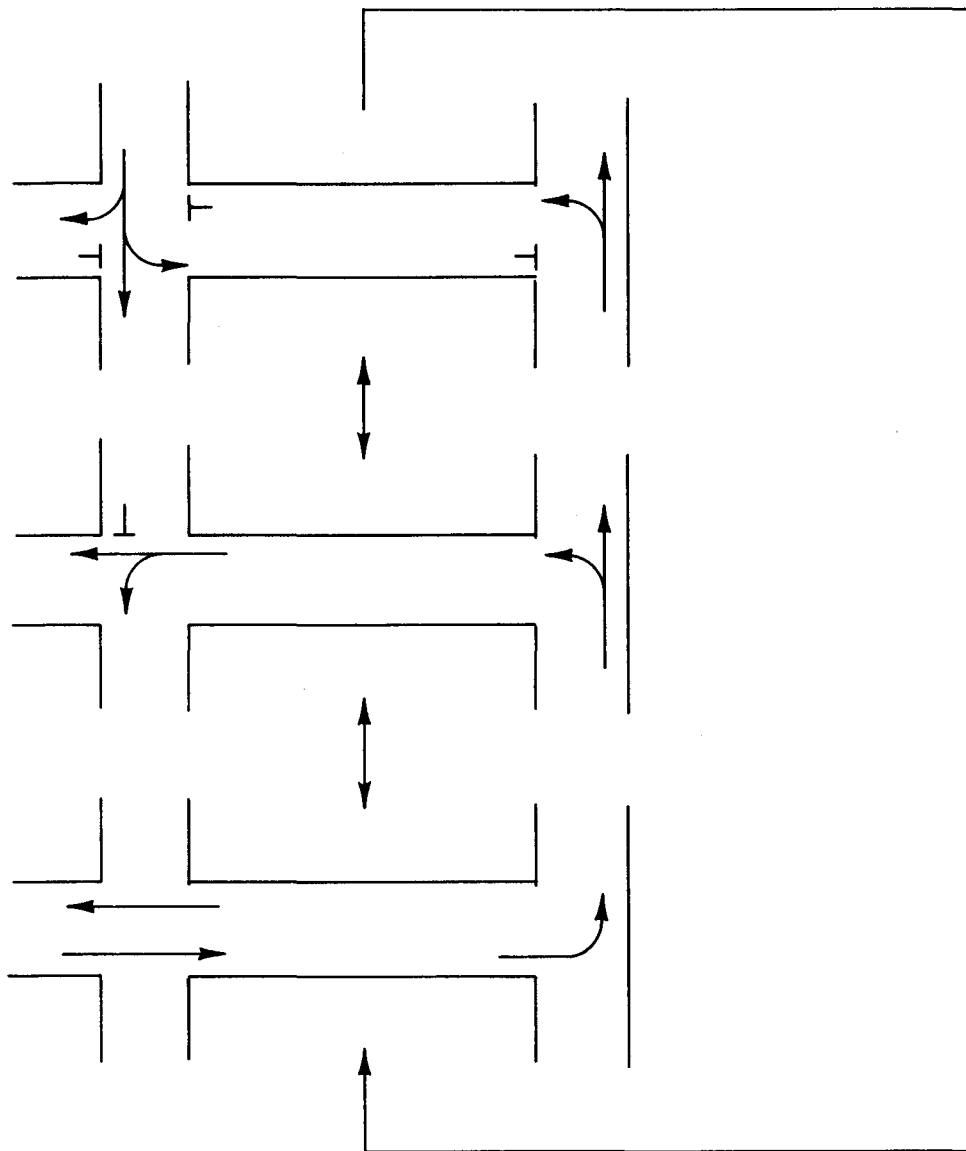


FIGURE 17

**THREE PHASE  
DIAMOND OPERATION**

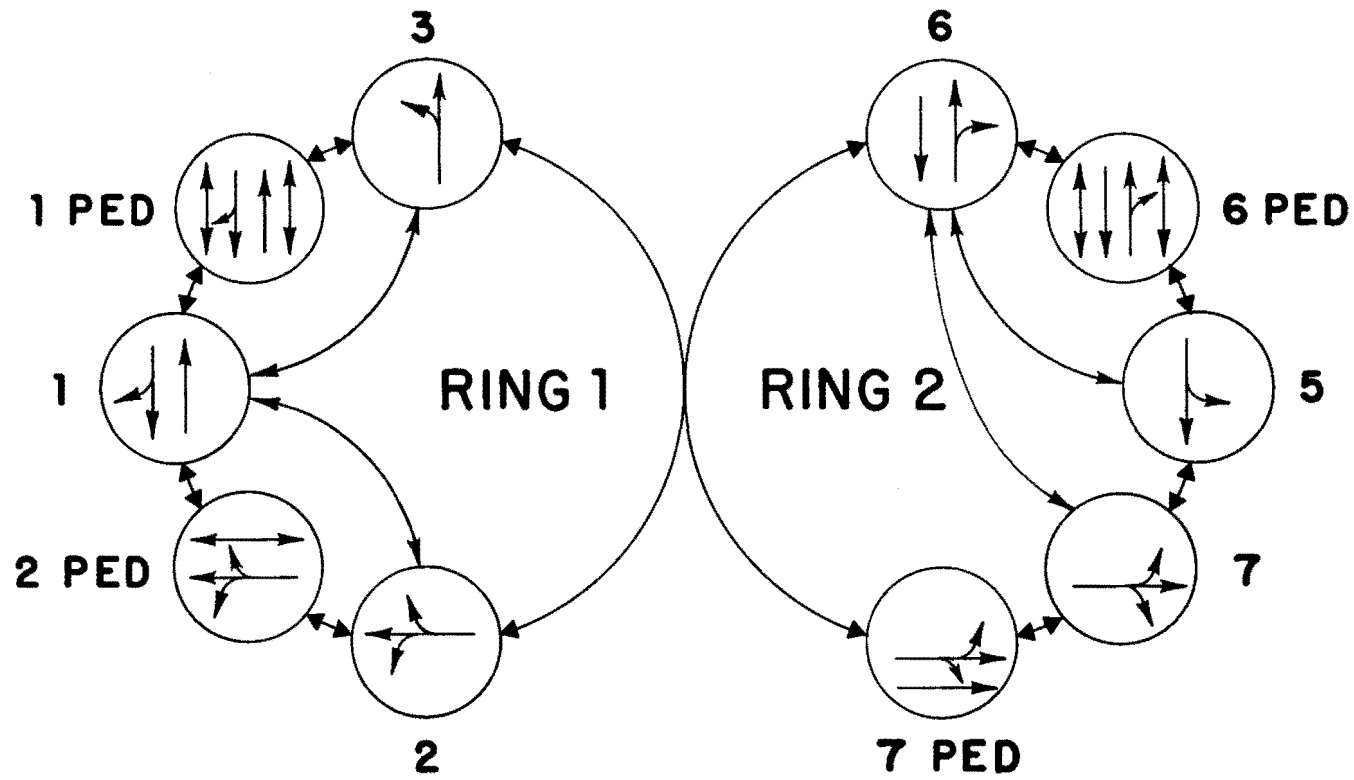


FIGURE 18

**COMPUTER CONTROLLED  
DIAMOND INTERCHANGE OPERATION**

The cost of the system, which includes six complete interchange traffic signal (twelve intersections) installations (including poles, signal heads, controllers, etc.), digital computer, interconnect cable, and detectors was \$726,000.

#### c. Present and Future Development

A software package has been developed which will permit the utilization of PASSER III for frontage road progression on a real time basis. Work is also underway for the implementation of PASSER II on a real time basis along arterial streets. Neither of these packages have been implemented in projects.

The algorithms have also been developed for a freeway control and surveillance software package but the software has not been developed. This will be the second module for the overall system.

The systems installed and being installed at present utilize 50 pairs of wire to each intersection. A Microprocessor Development Center has been purchased by the Department and development work is underway by the Computer Operations personnel of the Department's Division of Automation to develop a microprocessor based multiplexer which will reduce the number of wires to two pairs of wire per intersection with a further reduction in the future of eight intersections per two pairs of wire. It is planned for the microprocessor multiplexers and modems to be installed in the existing systems during the summer of 1981.

#### Conclusion

There is a need to consider a number of items when a traffic signal system is being studied and designed. These include:

1. The character and number of traffic patterns which occur within the signal system.
2. The number of phases required at intersections within the system.
3. The traffic volumes within the system and their relationship to intersection capacity.
4. The anticipated growth and change of the area which will affect traffic conditions within the signal system.
5. The need for coordination and interconnection with other signal systems.
6. The operation and maintenance capabilities and funds of the operating organization.
7. The funds available for installation of the system.
8. The anticipated benefits and utility that can be obtained from the system selected.

A number of types of traffic signal systems are available for installation ranging from fixed time systems to digital computer control. The two systems described in this paper are available for use where applicable. The results of the studies conducted on the systems installed to date show that these systems are providing effective and beneficial operation for existing and anticipated traffic pattern conditions.

REFERENCES

1. DARTS System - Paper developed by Mr. Harvey J. Beierle of District 15, San Antonio, Texas.
  
2. FACTS System - Paper prepared by Messrs. Richard H. Oliver, Blair Marsden, and Herman Haenel, and Development work carried out by Messrs. Elmer A. Koeppe, Alfred H. Kosik, and Herman Haenel of the Division of Safety and Maintenance Operations (D-18) and the Division of Automation (D-19) in Austin.

APPENDIX A  
DATA PREPARATION FOR THE SH 225 SYSTEM

When the SH 225 system first went into operation in late 1980, patterns prepared from 1976 traffic counts were implemented. These counts had been made by road-tubes and the count intervals ranged from 15 to 25 minutes. Manual turning movement counts had been made at the intersections and speed studies by tachograph runs. The counts were increased by 42% in an attempt to account for traffic growth in the area during the four years.

The traffic signals and computer were only a small portion of the entire project. Previously, SH 225 was a four-lane, undivided highway, and was expanded to the present frontage road design, with two or three lanes on each one-way frontage road. While the earlier traffic counts, increased by 42%, were not far from the current volumes, the increased roadway and intersection capacity was expected to make the initial patterns obsolete.

The initial patterns were implemented as an interim measure while the new patterns were being prepared. Most of the data was collected using the sampling detectors through the computer. There are 37 sampling detectors in the system, and they cover each of the lanes of all but three approaches. Traffic volumes were collected in five-minute intervals from 5:00 a.m. to midnight for one day. This was accomplished by outputting the detector data tables once an hour. Five-minute average detector occupancies were gathered simultaneously, as they were collected in the same tables. The occupancies were not used in the pattern development, but were used later when detectors were selected for cycle length and offset level selection. Manual turning movement counts were conducted by four people over two days. Road tube counts were taken on the three approaches without system detectors.

The OMNITAB computer program was used to provide volume and occupancy summaries; the detector data was stored in data sets by detector and time period. Initially, the detector volumes were summed by approach and graphs were printed showing the approach volumes for the entire period (5:00 a.m. to midnight) in five minute intervals. These graphs and the turning movement counts were used to develop the intersection splits for each of the patterns. A 120 second cycle length was found to be necessary in the morning peak and a 150 second cycle length for short periods in the afternoon. A 65 second cycle length could easily handle the traffic during non-peak conditions. Intersection splits were then developed for cycle lengths of 80, 95, 120, and 150 seconds for both the morning and afternoon peaks, and a 65 second cycle length for average conditions. PASSER III, a traffic signal optimization program written to design and evaluate signal settings at diamond interchanges, was used to determine the intersection minimum delay offsets for progression.

Each pattern is described by its offset level (inbound or outbound), cycle length, split set, and offset set (intersection offsets). The basic input table for the FACTS system which describes the patterns is the Pattern Selection Table (Figure A-1). The computer is referred to other tables by the Pattern Selection Table for the details of each pattern. The other primary tables which define the patterns are:

Intersection Phase Interval Table - Each phase interval that is used in the patterns is listed in this table. The output commands to the controllers and the green confirms (which verify the controller phase) are shown for each phase interval.

TABLE # 21 - PATTERN SELECTION TABLE - "PATT"

Figure A-1

	PATTERN #	OFFSET LEVEL #	PHASE PATTERN #	CYCLE LENGTH	A1+A2/TOTAL RATIO		A1/A1+A2 RATIO	THRESHOLD		THRESHOLD			
					LOWER THRESHOLD	UPPER THRESHOLD	THRESHOLD	THRESHOLD		THRESHOLD			
								SPLIT SET #	OFFSET SET #	SPLIT SET #	OFFSET SET #		
		1	2	3	4	5	6	7	8	9	10		
		OFL#	PPAT	CYLN	TLTH	TUTH	TRTH	LTSS	LTOS	GTSS	GTOS		
LIGHT	1	1	1										
	2												
	3		2										
	4												
	5												
OUTBOUND	6	2	3										
	7												
	8												
	9		4										
	10												
	11												
	12			5									
	13												
14													
AVERAGE	15	3	6										
	16												
	17		7										
	18												
	19												
	20												
	21			8									
	22												
23													
INBOUND	24	4	9										
	25												
	26												
	27		10										
	28												
	29												
	30			11									
	31												
32													



Intersection Phase Sequence Table - The sequences of the phase intervals listed in the table described above are shown in this table for each of the patterns.

Intersection Phase Pattern Table - This table defines which phase sequence is to be used for each pattern. Also, the intervals during which transition correction can occur, the amount of time that can be subtracted or added in each transition phase, and whether to add or subtract during transition are defined for each pattern.

Intersection Split Set Table - The phase splits (interval times) for each cycle length-offset level-split combination are shown here. The specific split set is referred to directly from the Pattern Selection Table.

Offset Set Table - The intersection offsets for each cycle length-offset level-split combination are shown here. As is the case for the split sets, the specific offset set is referred to directly from the Pattern Selection Table.

The data for these tables is obtained from the time-space diagrams generated by PASSER III, with the exception of the transition values, which are calculated separately.

During normal operations, FACTS samples selected detectors to measure traffic demand, and compares them with preset threshold values to determine the correct cycle length, offset level, and split for each subsystem. The system calculates the following parameter for each detector from the stored detector data:

$$\text{Detector Parameter} = [\text{Volume} + F(\text{Occupancy})]/L,$$

where L is the number of lanes the detector covers (one lane in all cases on SH 225), and F is a weighting factor. Initially, this factor is set at 0.5, but it can be varied to give more or less weight to the one-minute occupancy at each detector. The cycle length selection parameter is then calculated by summing the parameters of the individual detectors assigned to cycle length selection and dividing by the number of these detectors. The offset level selection parameter is calculated using individual detectors assigned as either inbound or outbound detectors. The individual inbound detector parameters are summed and divided by the number of inbound detectors. A similar value is calculated for the outbound detectors. The offset level selection parameter is then determined by dividing the inbound detector value by the sum of the inbound and outbound detector values.

OMNITAB was used to generate a volume plus occupancy plot for each detector, using 0.5 as the weighting factor on the occupancy. Detectors were then selected that showed the desired characteristics for cycle length and/or offset level selection. Ultimately, eight detectors were selected for cycle length selection and five for offset level selection (two inbound and three outbound detectors). Several OMNITAB runs were made, using different detectors, until the summary graphs showed definite peaks and off-peaks in a relatively smooth curve. The threshold values are then picked from these plots. Between five and ten detectors were chosen in each case. If too few are used, the resulting summary curve is not smooth, and the cycle length and/or offset level would tend to oscillate between patterns as it tries to respond to isolated traffic surges that would

not necessarily represent system needs. If too many detectors are selected, the system would only respond to large scale changes, and traffic increases or decreases that affect portions of the system may not be recognized, even though a pattern change may be beneficial.

These new patterns have been implemented on SH 225, and we are now working out the minor problems. The last two steps of the pattern preparation, which will be completed shortly, are use of the local options (skips and gap outs) and the development of additional split sets to allow the computer to vary the intersection splits without changing patterns.