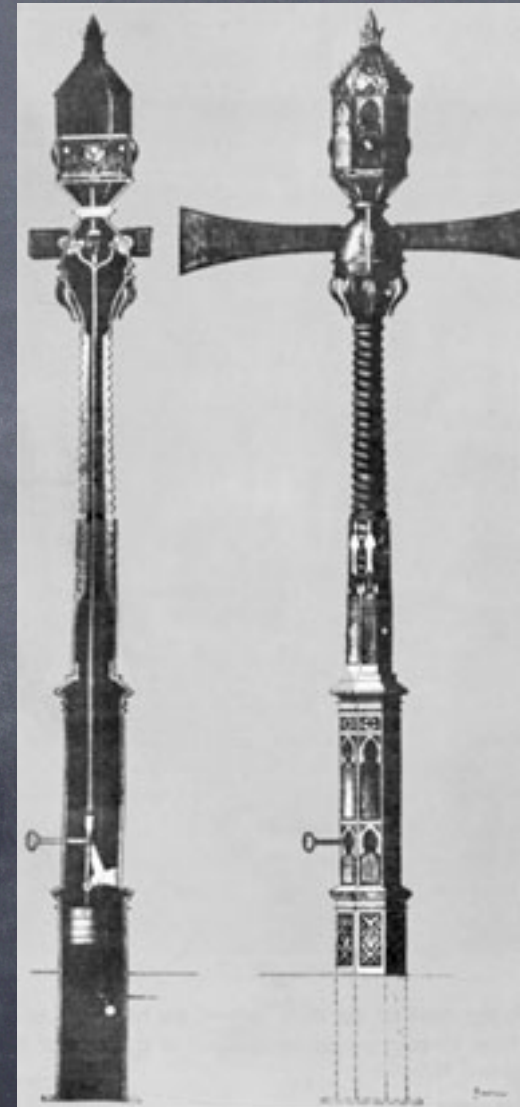


Traffic Analysis at Signalized Intersections

David Levinson
(based on notes
by Henry Liu
University of
Minnesota)

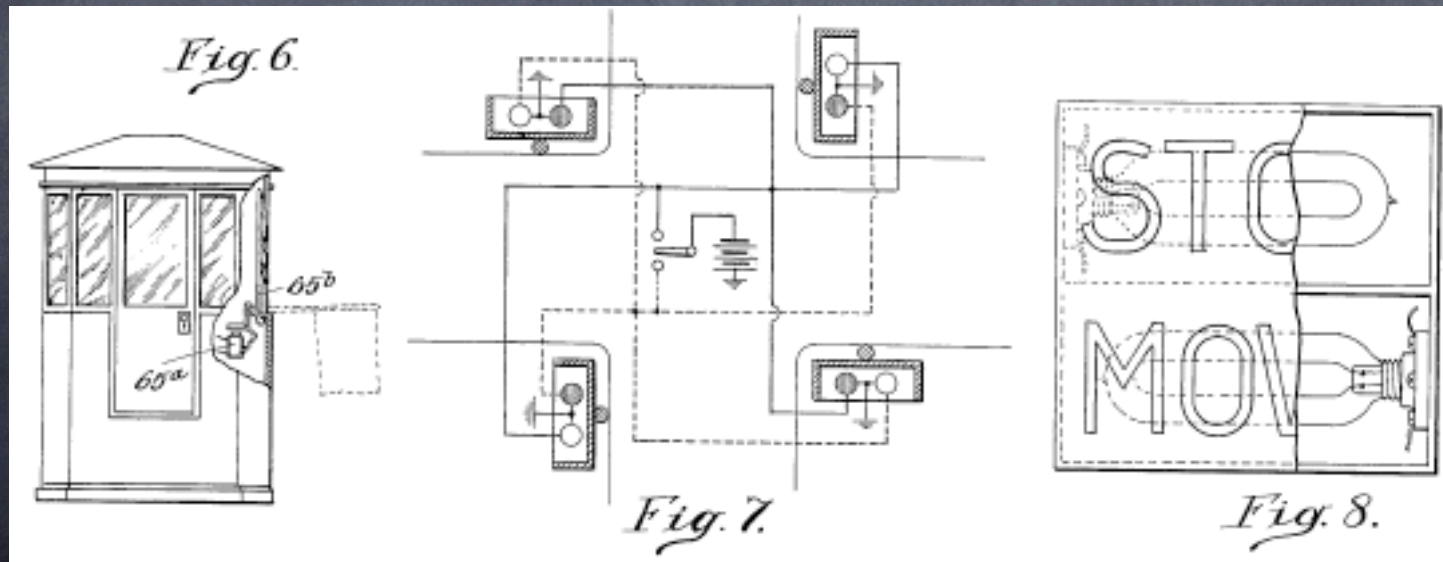
History of Signalized Intersections

1868 – London, UK
– Manually operated
semaphores (flags)



History of Signalized Intersections

1914 - Cleveland, OH
- 1st Electric Signal



History of Signalized Intersections

1917 – Detroit, MI
– Amber color introduced

Hanging Traffic Light

Detroit, Michigan, was the location for the world's first three-color, four-direction traffic signal in 1920.

Gift of Police Department, City of Detroit
Designed by William L. Potts



History of Signalized Intersections

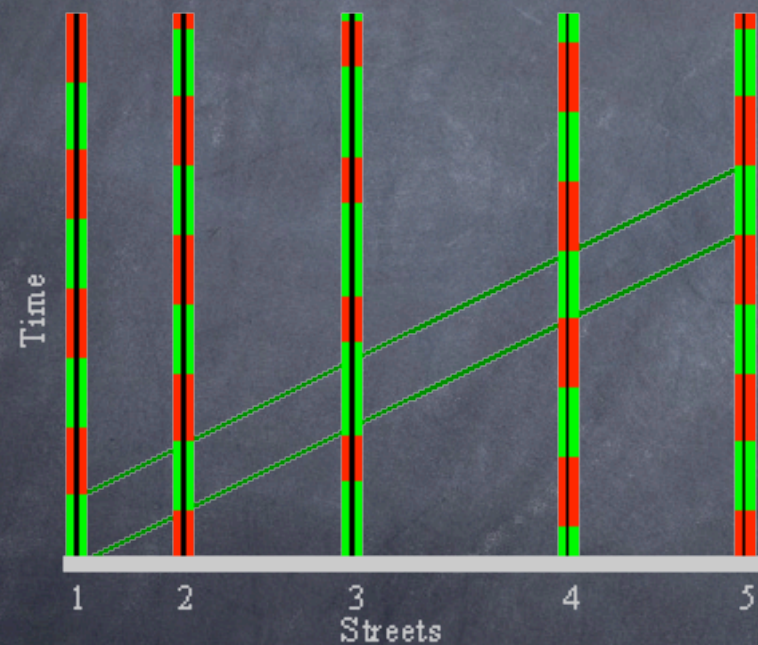


Image based on [Banks, 2002]

Space-time diagram

1922 – 1st Progression System, New York City

History of Signalized Intersections

1926 - 1st Actuated Signals

Horn actuated
signal



Purposes:

1. Orderly assigned Right-of-Way
2. Safety
3. "Not" a panacea !

Advantages and Disadvantages

- Why do we use traffic signals? []
- What are the advantages and disadvantages?

Advantages and Disadvantages

1. Orderly Movement

2. Reduce right angle accidents

3. Increase Capacity

4. Allow Crossing

5. Coordination

6. Driver Confidence

7. Cost Effective

1. Increase Delay

2. Increase Rear End Accidents

3. Promote Disrespect when unwarranted or misapplied

4. Driver Irritation – improperly timed

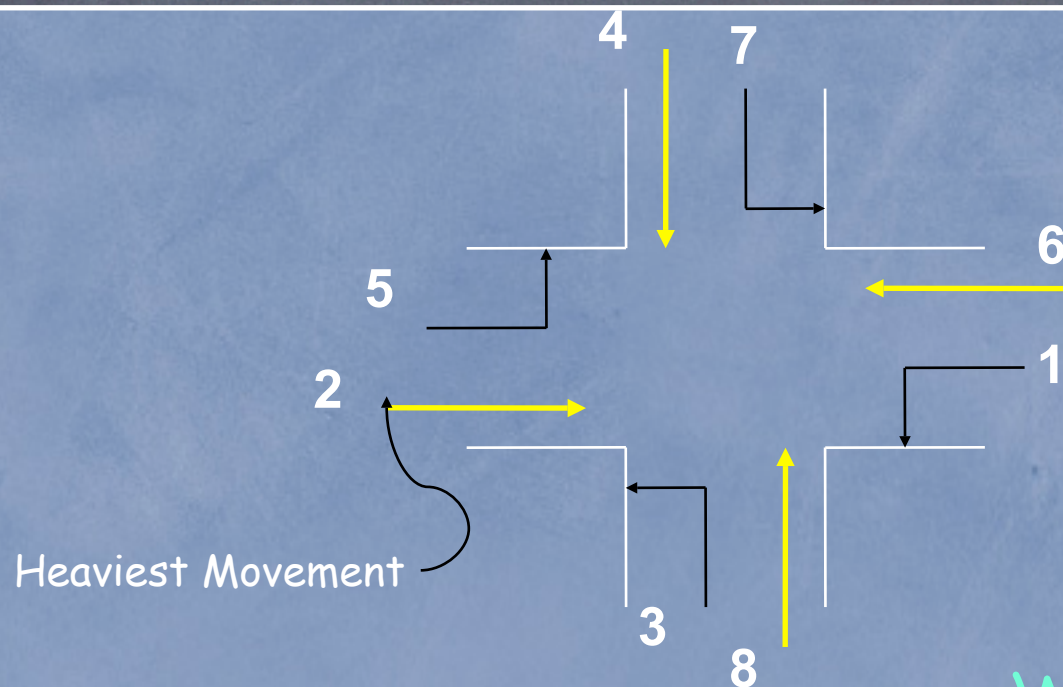
Definitions & Related Terminology

- **Approach** – Lane or group of lanes through which traffic enters an intersection.
- **Cycle** – One complete signal sequence (all approaches).
- **Cycle Length (C)** – Total time (sec.) to complete a cycle for all approaches.
- **Traffic Signal Phase (φ)** – part of a cycle allocated to specific movement(s) that receive the right of way simultaneously.

NEMA Phasing Convention

Left Turn Movements: Odd numbers one less than opposing through movement designation

Through Movements: Even numbers clockwise starting with heaviest movement



What about right turns?

Definitions & Related Terminology

- **Indication** – Illumination of one or more signal lenses permitting or prohibiting traffic movement.
- **Interval** – Period of time during which all signal indications remain the same for all approaches.
- **Change Interval** – Yellow time plus all-red time that provides for clearance of the intersection (Yellow + All-Red Time)
- **Traffic Signal Controller** – controls sequence, duration and logic.

Movement

- **Protected movement:** A movement that has the right-of-way and does not need to yield to conflicting movements, such as opposing vehicle traffic or pedestrians.
- **Permitted movement:** A movement that must yield to opposing traffic flow or conflicting pedestrian movements.

Definitions & Related Terminology

- **Green Time (GT)** – time within cycle in which an approach has **green** indication.
- **Red Time (RT)** – time within cycle in which an approach has **red** indication.
- **Yellow Time (YT)** – time within cycle in which an approach has **yellow** indication.
- **All-Red Time (AR)** – time within cycle in which all approaches have **red** indication.

Definitions & Related Terminology

Lost Time (LT) – Time (sec) during which intersection not effectively used by any approach, including start-up lost time and clearance lost time.

Effective Green (g) – Time (sec) effectively used by an approach for traffic movement ($g = GT + Y + AR - LT$)

Effective Red (r) – Time (sec) not effectively used by an approach for traffic movement ($\text{cycle time} - g$)

Discharge Headways

The discharge headway is based upon expected highway after the point at which headways stabilize. This headway stabilizes at 2.14 seconds for the sixth and subsequent vehicles.

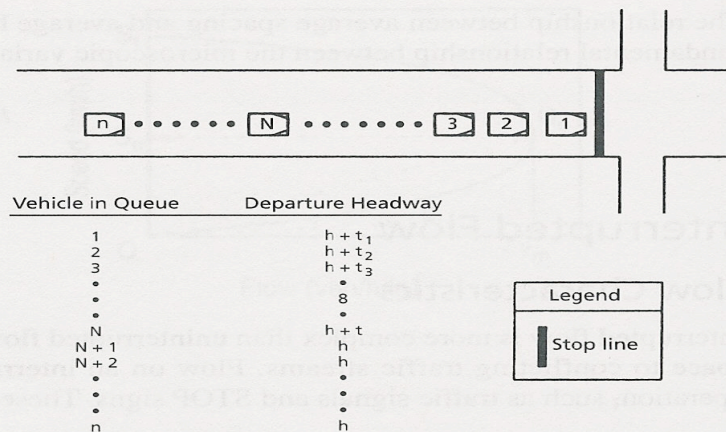


Figure 4-3 Conditions of Traffic Interruption in an Approach Lane of a Signalized Intersection

Source: Transportation Research Board, *Highway Capacity Manual*, Special Report 209, Washington, D.C.: TRB, National Research Council, 1994 (revised 1997).

TABLE 20-1 Computations related to Figure 20-1

Queue Position	Observed Avg. Headway (sec)	Estimated Headway (*)	Difference, Observed Minus Actual (sec)
1	2.61	2.14	0.47
2	3.00	2.14	0.86
3	2.52	2.14	0.38
4	2.37	2.14	0.23
5	2.21	2.14	0.07
> 5	2.14	2.14	0.00
Start-up lost time =			2.10 sec

*Based upon value for queue positions greater than five.

$$l_1 = \sum e(i) = \sum (h_i - h)$$

Saturation Flow Rate

The saturation flow rate is computed as:

$$s = 3600/h$$

where s = saturation flow rate (vphgpl),

h = discharge headway (sec/veh)

Lost Time

The start-up lost time is estimated by the sum of the differences between the observed headway for each of the vehicles before the headway stabilizes.

Lost Time

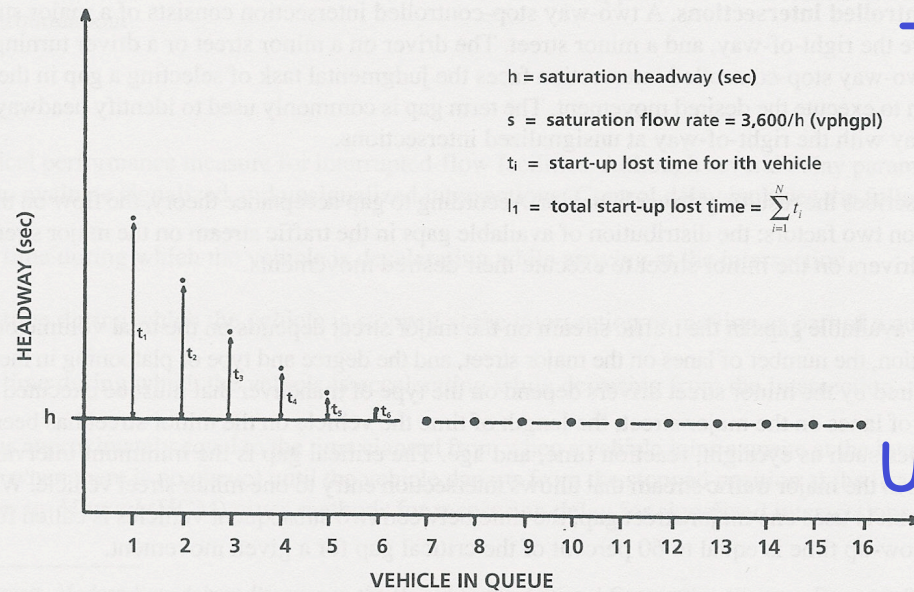


Figure 4-4 Concept of Saturation Flow Rate and Lost Time

TRB, Highway Capacity Manual, 1997 update.

Start-up lost time

$$l_1 = \sum e(i) = \sum (h_i - h)$$

Time req'd to clear N veh.

$$T = l_1 + h(N)$$

Greenshields (1947)

$$T = 3.7 + 2.1(N)$$

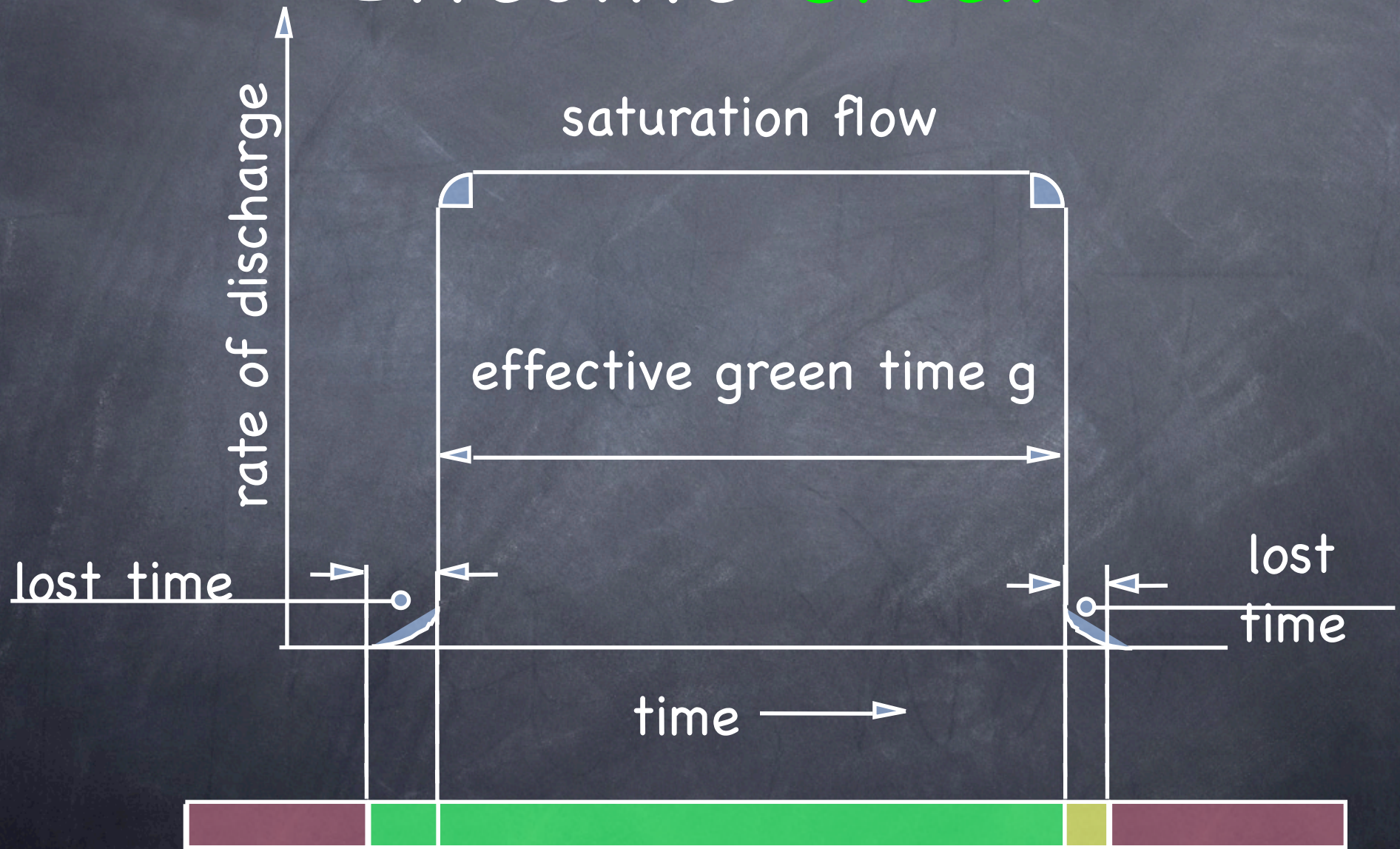
Updated Greenshields (1978)

$$T = 3.1 + 2.1(N)$$

Saturation Flow

$$s = 3600/h = 3600/2.1 = 1714 \text{ vphpl}$$

Effective Green



Definitions & Related Terminology

- **Saturation Flow (s)** – Maximum flow that can pass through an intersection from a given approach, if that approach is allocated all of the cycle time as effective green with no lost time.
- **Approach Capacity (c)** – Maximum flow that can pass through an intersection under prevailing highway and traffic conditions, given the effective green time allocated to the approach
($c = s * g/C$)

Types of Control

- Pretimed Signal
- Semi-Actuated Signal
- Fully-Actuated Signal

Pre-timed Signal

- Pre-determined schedule
- Fixed cycle lengths
- Need traffic history
- Several timing options possible
- Good at predictable locations or downtown CBD

Pre-timed Signal – Advantages and Disadvantages

- Simple
- Can be coordinated
- Easy to field adjust
- Can handle peak and off peak conditions

- Cannot react to short-term demand changes
- Can cause excessive Delays
- Sometimes results in disrespect ==> Liability

Semi-Actuated Signal

- Major Rd = High Volumes;
Minor Rd = Low Volumes
- Detectors on Minor Approaches
- Minor phase (ϕ) = Min. Green Interval
- Major phase (ϕ) = Extends Indefinitely
- Minor Rd gets served upon actuation
{and major roadway change interval after time out}

Fully-Actuated Signal

- Varying traffic demand; not homogeneous or probable FLOW
- Detectors on all approaches
- Phases have an initial interval which provides time for starting / standing vehicles
- Green interval extended by preset unit extension.... up to maximum limit of allocated time
- Yellow and red intervals preset for phases

Max Out/Gap Out

- Green is terminated by one of two mechanisms
 - Gap Out (GO)
 - Max Out (MO)
- The length of a phase is constrained to a range of the minimum green to the maximum green
- See next page

Operations of an Actuated Phase

Unexpired portion
of unit extension

1st actuation on a conflicting

Max Out operation

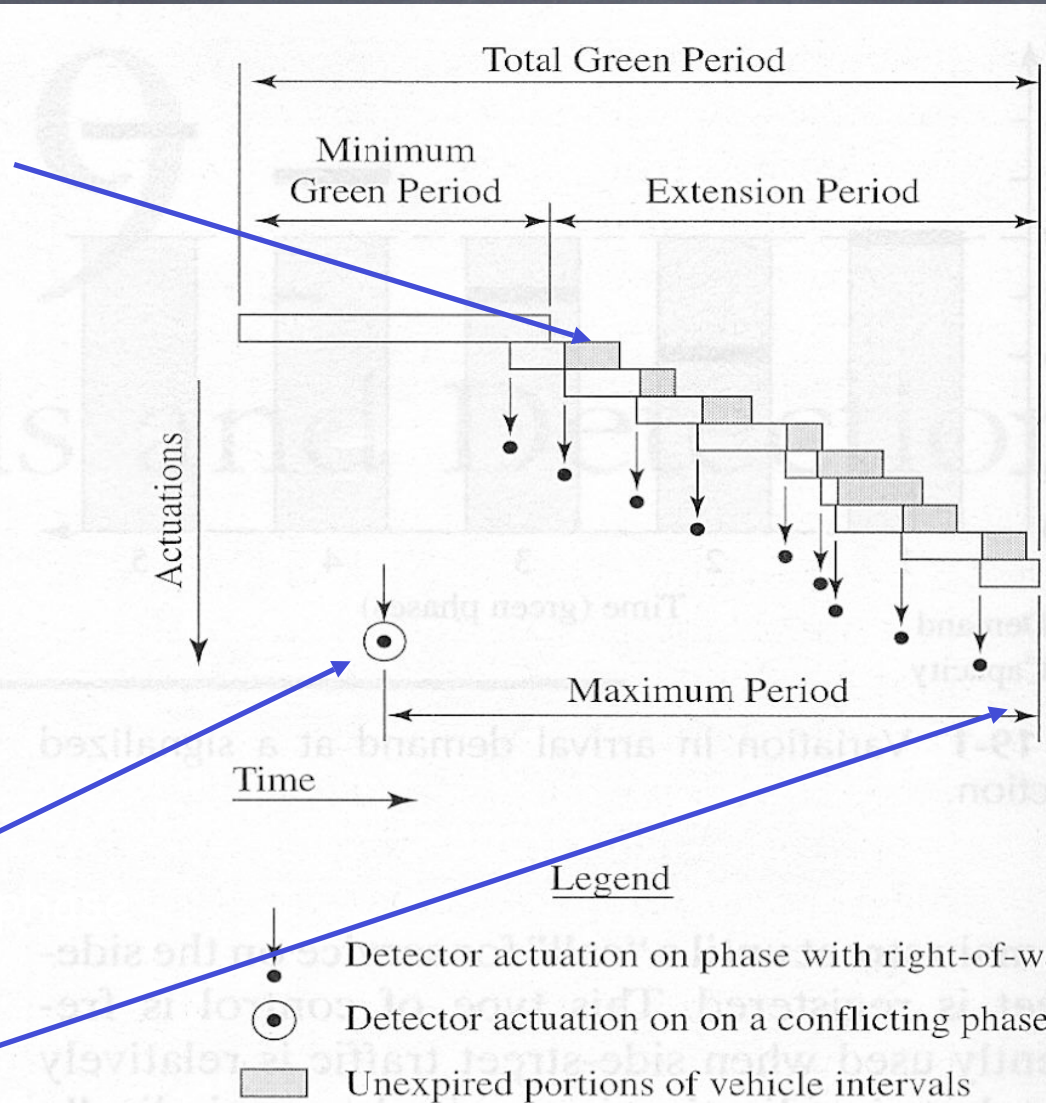
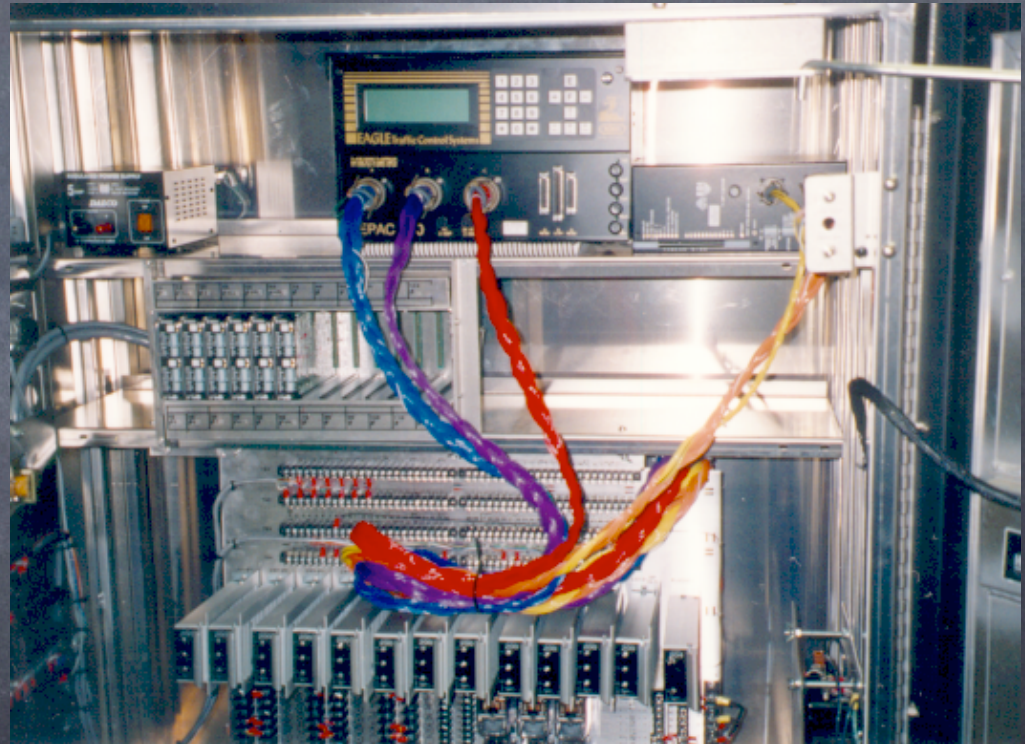


Figure 19-2 Operation of an actuated phase. [Used with permission of Institute of Transportation Engineers, from *Traffic Detector Handbook*, 2nd Ed., JHK & Associates, p. 66. Copyright © Institute of Transportation Engineers.]

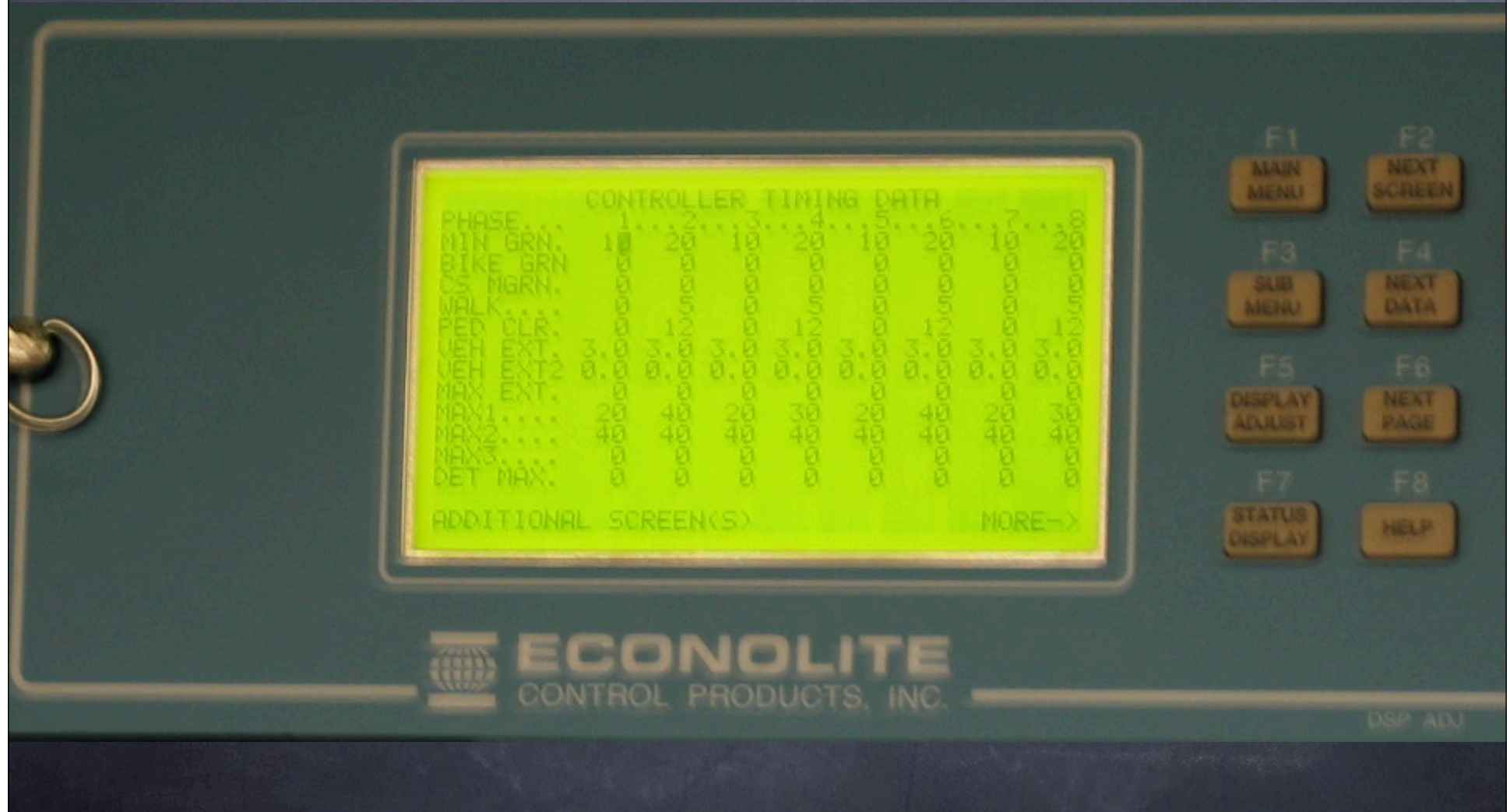
Signal Detectors and Controllers

- Most common controllers – NEMA controllers
- Advanced controllers
 - Type 170
 - Type 2070
 - Advanced Transportation Controllers (ATC)

NEMA Controller



Econolite NEMA Controller



170 Controller



Transit Signal Priority System Components

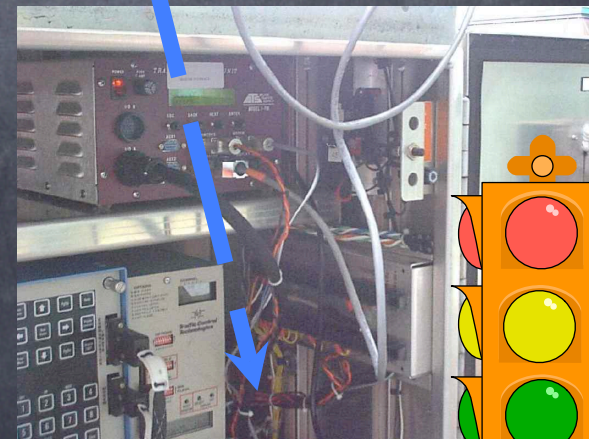
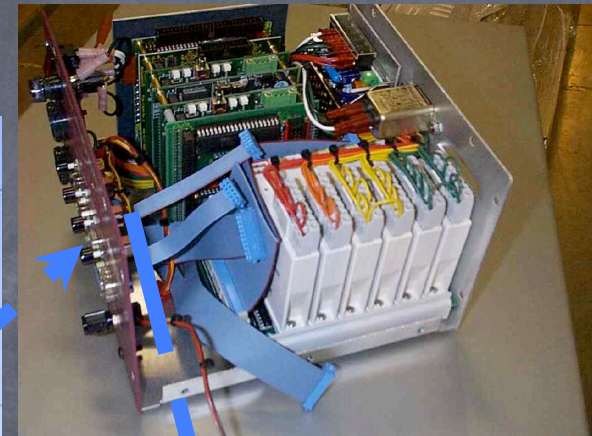
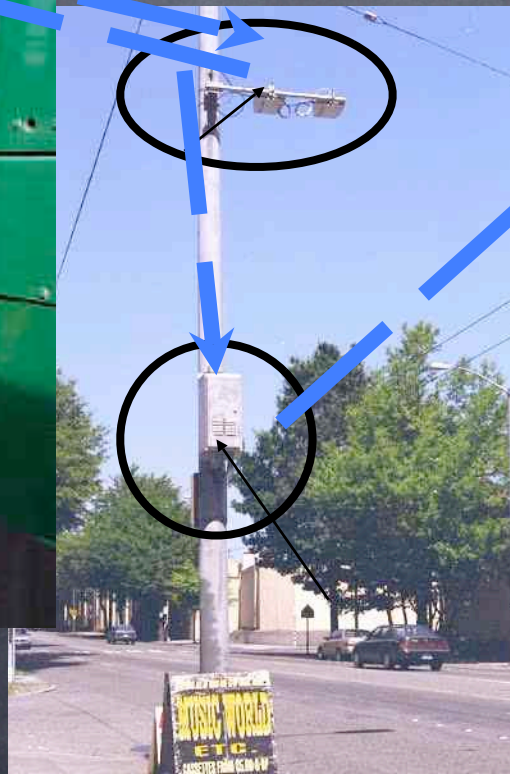
Tag

Interface Unit



Tag Interface
Unit for Dynamic
Data

Antenna



Questions

- Questions?

Abbreviations

Key Terms

Variables