

***Time – Distance – Speed
Relationships***

Time – Distance – Speed

***If you know any two you
can find the third.***

distance
traveled

90 miles

speed

30 mph

time
taken

3 hrs

$$S = d / t$$

Constant speed:

$$d = S t$$

$$t = d / S$$

$$S = d / t$$

In these examples the units of the
Time, Distance, and Speed were

Time	Distance	Speed
HOURS	MILES	MPH

But in collision reconstruction
it's a little more complicated

Time	Distance	Speed
SECONDS	— FEET —	MPH

But in collision reconstruction
it's a little more complicated

Time	Distance	Speed
SECONDS	FEET	MPH

We have to convert mph to ft/sec

1 mile
—
hour



?

ft
—
sec

$$\frac{1 \text{ mile}}{\text{hour}} = \frac{5280 \text{ ft}}{3600 \text{ sec}} = 1.466\dots \frac{\text{ft}}{\text{sec}}$$

$$\frac{1 \text{ mile}}{\text{hour}} = \frac{5280 \text{ ft}}{3600 \text{ sec}} = 1.466\dots \frac{\text{ft}}{\text{sec}}$$

I use 1.47 for my calculations

mph $\xrightarrow{\text{multiple by 1.47}}$ ft/sec

$$30 \text{ mph} (1.47) = 44.1 \text{ ft/sec}$$

ft/sec $\xrightarrow{\text{divide by 1.47}}$ mph

$$103 \text{ ft/sec} \div 1.47 = 70 \text{ mph}$$

Constant speed:

(speed in mph)

$$d = 1.47 S t$$

$$t = \frac{d}{1.47 S}$$

$$S = \frac{d}{1.47 t}$$



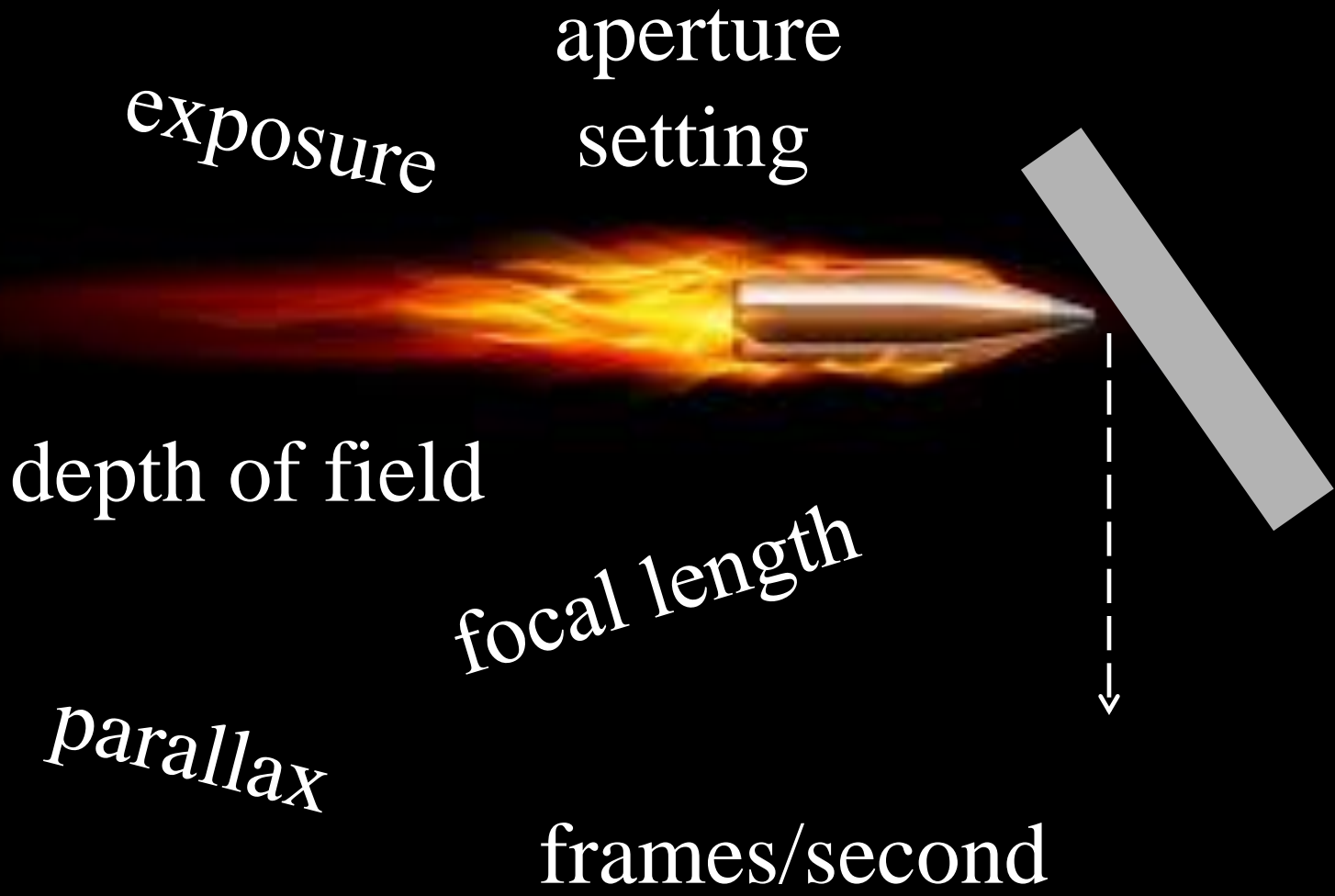
ROH NOCL 01

$$S \text{ (ft/sec)} = d / t$$

d from landmarks in video

t from frames/sec recording
rate

bulletproofing your video analysis



bulletproofing your video analysis

TEST RUN AT KNOWN SPEED (RADAR)

SAME TIME OF DAY

SAME VIDEO CAMERA

SAME RECORDER

SAME VIDEO DOWNLOAD METHOD

SAME ANALYSIS METHODOLOGY

OTHER USES OF TDS ANALYSES

TO ESTIMATE VEHICLE SPEED (from GPS, video, etc.)

TO FIND AVAILABLE PRT from sight distance

TIME LAPSE DRAWING OF PRE-IMPACT POSITIONS

TO VERIFY WITNESS STATEMENTS

TO SHOW INCONSISTENCIES IN RECONSTRUCTION

HYPOTHETICALS

How much time would it take for a vehicle to...

Based on CDR data, where was the vehicle at $t = \dots$

Determining the available PRT
when the visibility distance
is known

(time available for avoidance)

Locus: Brick Rd., Adams, AX
Scale: 1:240 (1 inch = 20 feet)

RP: (reference point) utility marker #45/31

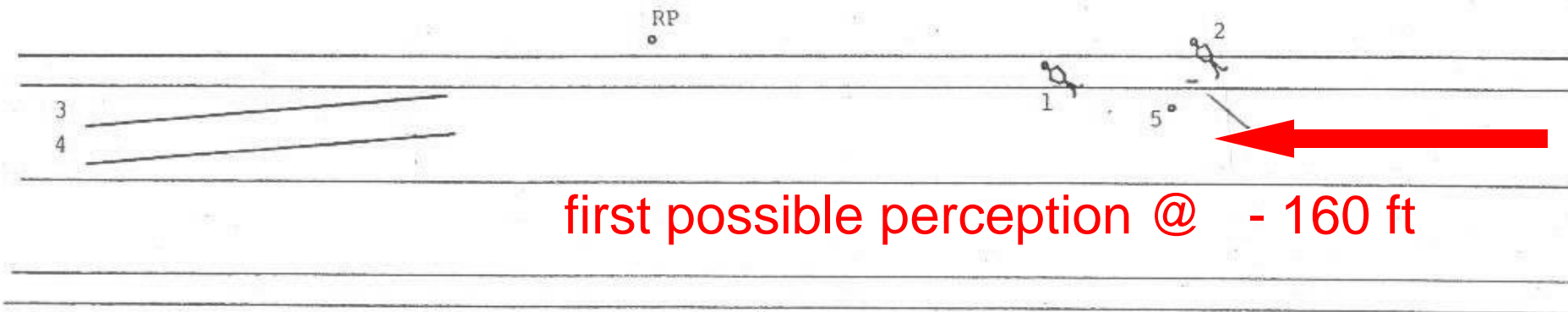
Evidence: 1 FRP Brock
2 FRP MacBride
3 skid mark
4 skid mark
5 hood ornament
6 shoe scuff mark

Measurements: R. Bishop

Drawing: R. Bishop

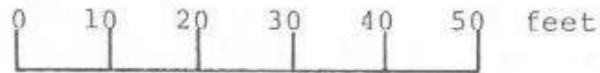
D.O.I. 12/20/XX

State v. Farner



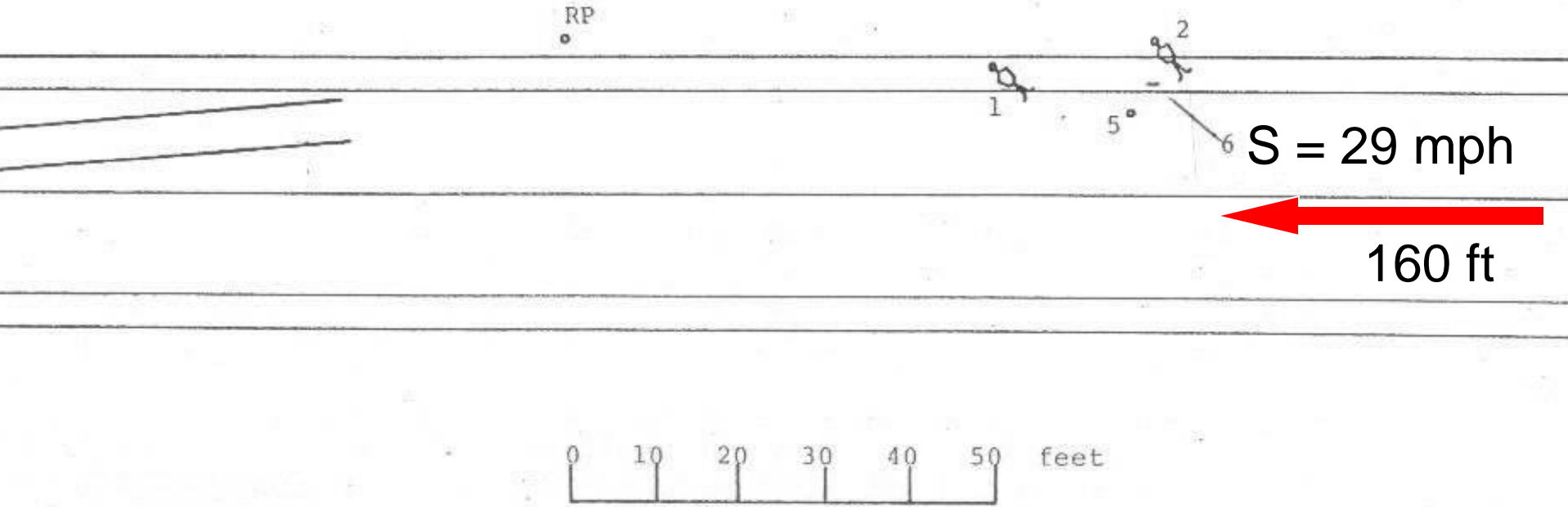
first possible perception @ - 160 ft

S = 29 mph



RP: (reference point) utility marker #45/31
Evidence: 1 FRP Brock
2 FRP MacBride
3 skid mark
4 skid mark
5 hood ornament
6 shoe scuff mark
Measurements: R. Bishop
Drawing: R. Bishop
D.O.I. 12/20/XX

$$t = \frac{d}{1.47S}$$



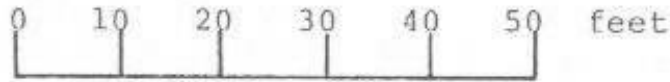
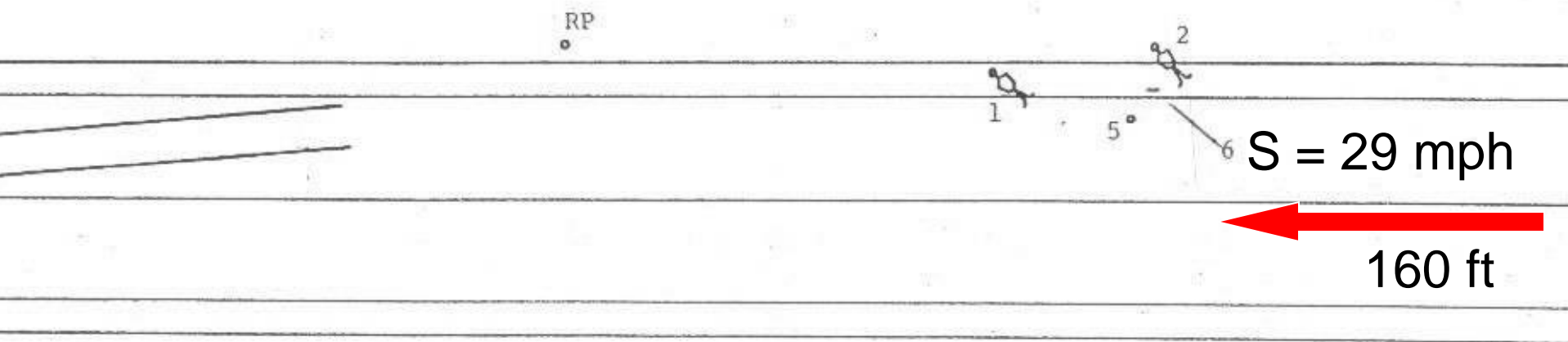
How much time was there to react ?

RP: (reference point) utility marker #45/31

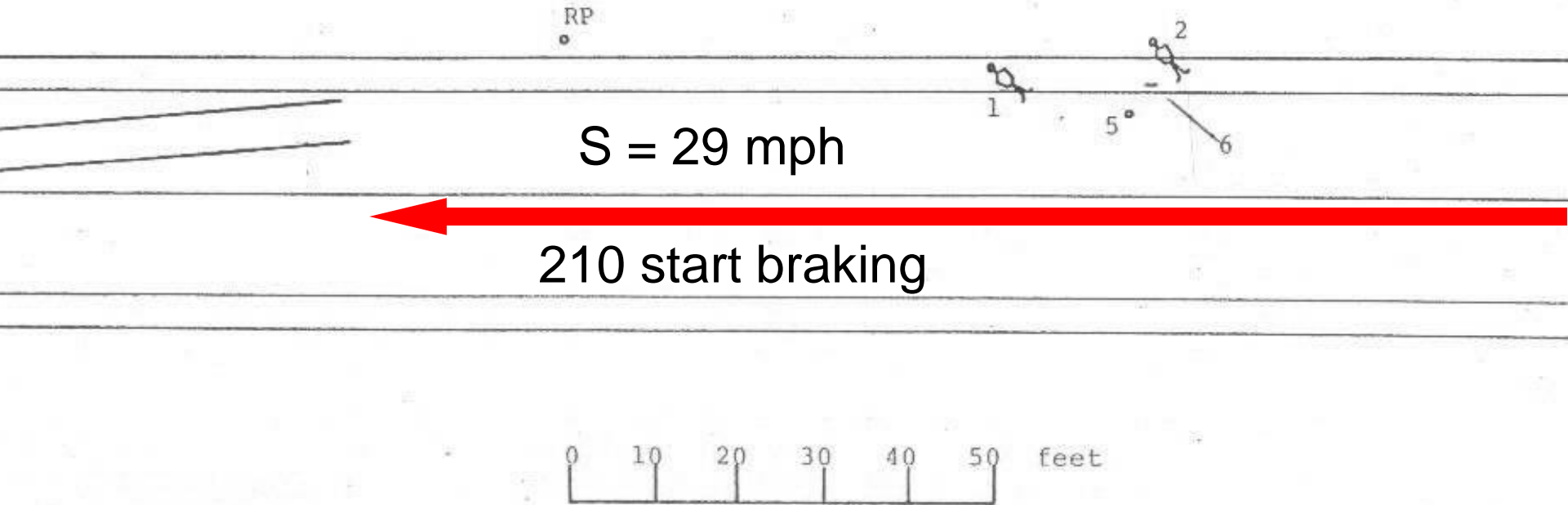
- Evidence:
- 1 FRP Brock
 - 2 FRP MacBride
 - 3 skid mark
 - 4 skid mark
 - 5 hood ornament
 - 6 shoe scuff mark

Measurements: R. Bishop
Drawing: R. Bishop
D.O.I. 12/20/XX

$$t = \frac{d}{1.47S} = 3.75 \text{ sec}$$



RP: (reference point) utility marker #45/31
Evidence: 1 FRP Brock
2 FRP MacBride
3 skid mark
4 skid mark
5 hood ornament
6 shoe scuff mark
Measurements: R. Bishop
Drawing: R. Bishop
D.O.I. 12/20/XX



What was the actual PRT?

RP: (reference point) utility marker #45/31

- Evidence:
- 1 FRP Brock
 - 2 FRP MacBride
 - 3 skid mark
 - 4 skid mark
 - 5 hood ornament
 - 6 shoe scuff mark

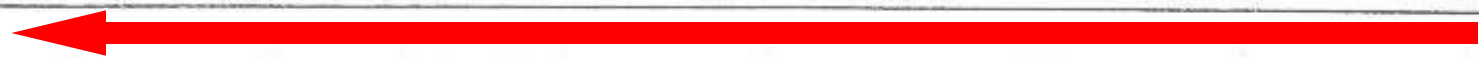
Measurements: R. Bishop
Drawing: R. Bishop
D.O.I. 12/20/XX



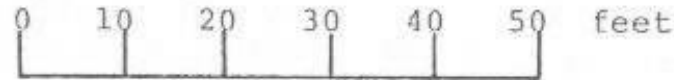
$$t = \frac{d}{S} = 4.92 \text{ sec}$$
$$1.47 \text{ S}$$

RP

S = 29 mph



210 ft



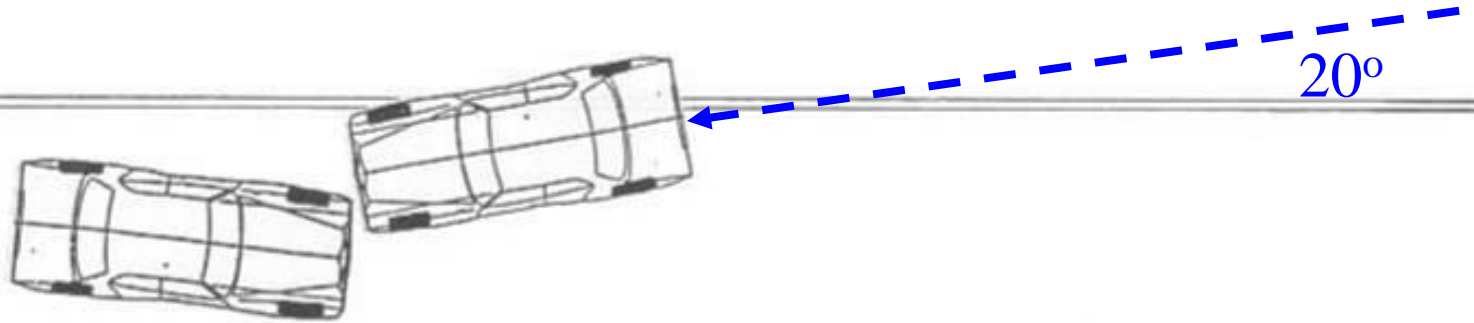
Crossing center line:

Did victim have enough time to
initiate an evasive action ?

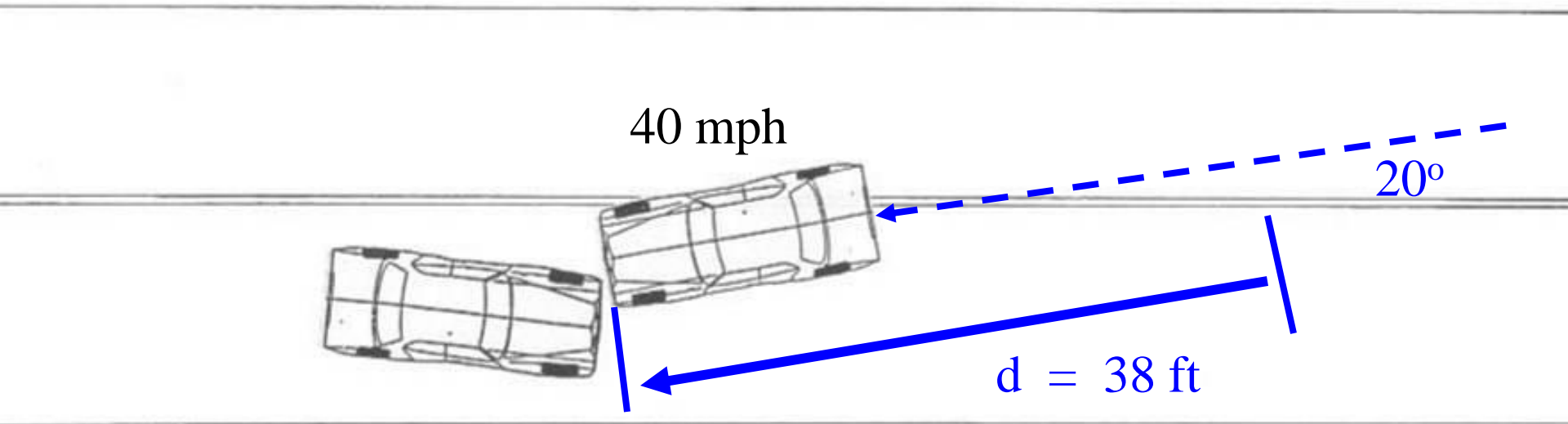


CROSSING CENTER LINE

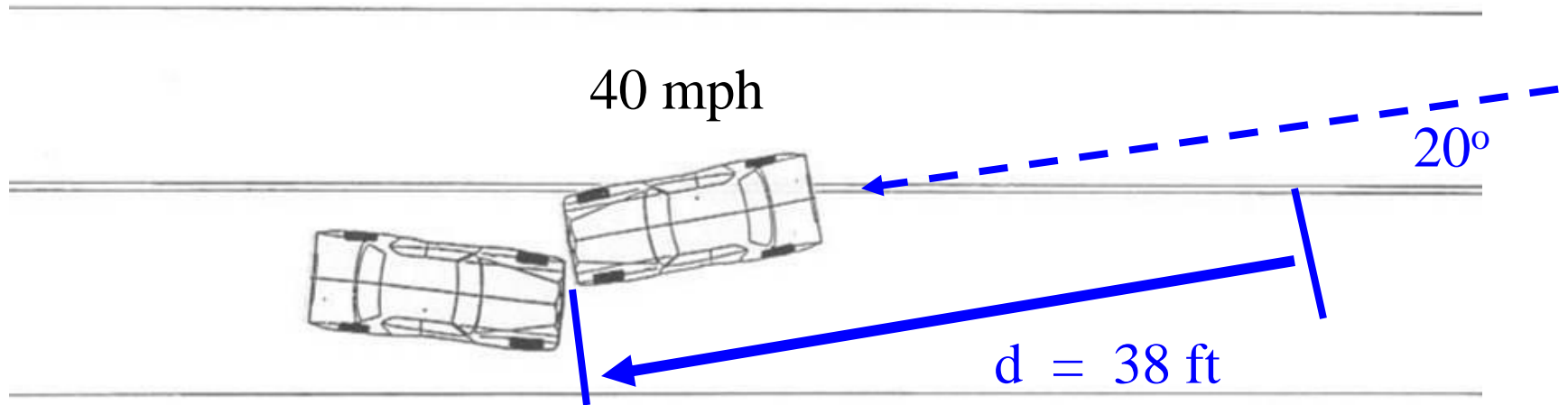
Police report concludes that defendant vehicle, traveling at 40 mph, crossed center line. Victim tried to avoid collision by turning away.



Did victim have enough time to react, and turn away ?

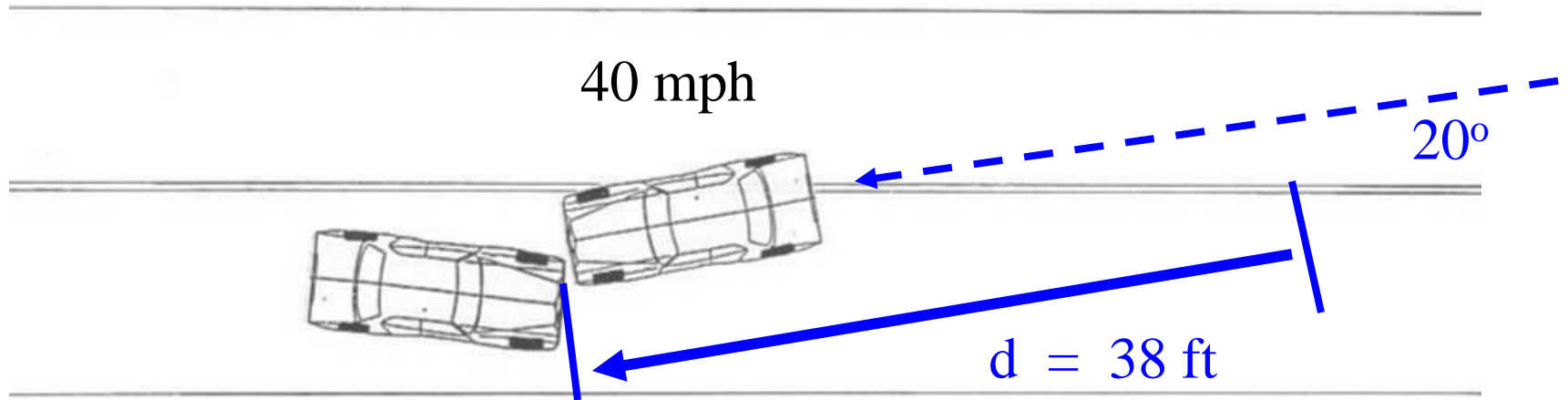


Did victim have enough time to react, and turn away ?



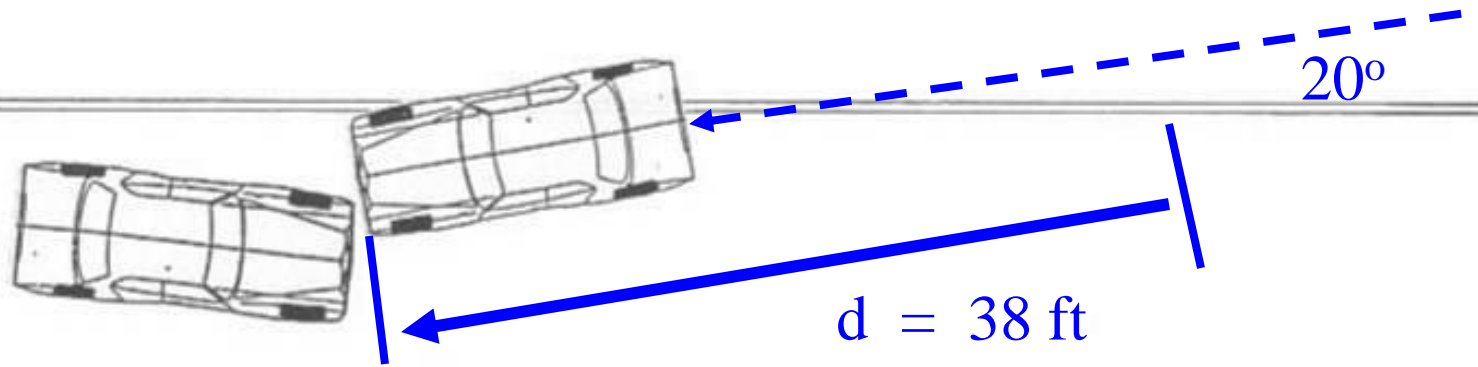
$$t = \frac{d}{1.47S}$$

Did victim have enough time to react, and turn away ?



$$t = \frac{d}{1.47S} = \frac{38}{1.47(40)}$$

Did victim have enough time to react, and turn away ?



$$t = .64 \text{ sec}$$

***Using Data from the EDR
Report for T-D-S Calculations***

How to know when the danger presented, and the PRT of driver 2

2



What is the PRT of the driver?



EDR data?

1



**EDR report
from MV #1**

Pre-Crash Data -5 to 0 Seconds (1st Prior Event)

Time (sec)	Vehicle Speed (MPH [km/h])	Accelerator Pedal, % Full (%)	Percent Eng Thro (%)	Injection Quantity (mm ³ /st)	Engine (RPM)
-5.00	0.0 [0]	0.0	0.0	Invalid	60
-4.50	0.0 [0]	0.0	0.0	Invalid	60
-4.00	0.0 [0]	0.0	0.0	Invalid	60
-3.50	0.0 [0]	0.0	4.0	Invalid	60
-3.00	1.9 [3]	25.5	10.0	Invalid	1,10
-2.50	5.0 [8]	34.5	15.0	Invalid	1,40
-2.00	8.1 [13]	34.5	15.0	Invalid	1,50
-1.50	10.6 [17]	36.5	17.0	Invalid	1,80
-1.00	12.4 [20]	39.0	19.0	Invalid	2,10
-0.50	13.7 [22]	0.0	3.5	Invalid	2,10
TRG(0)	Invalid	Invalid	Invalid	Invalid	Inva

Pre-Crash Data -5 to 0 Seconds (1st Prior Event) - Table 2 of 4

Time (sec)	ABS Control Status	BOS Control Status	Brake Oil Pressure (Mpa)	Longitudinal Acceleration, VSC Sensor (m/s ²)	Yaw F (deg)
-5.00	OFF	OFF	1.97	0.072	0.0



EDR report from MV #1

Pre-Crash Data (Most Recent Event - table 1 of 5)
(the most recent sampled values are recorded prior to the event)

Time Stamp (sec)	Vehicle Event Recorder Status	Engine RPM	Speed, Vehicle Indicated (MPH [km/h])	Engine Throttle, % Full	Accelerator Pedal, % Full	Raw Manifold Pressure (kPa)	Serv Brk	Open	No
-5.0	Complete	4,960	62 [99]	76.4	77.2	97	Off	Open	No
-4.9	Complete	4,960	62 [100]	76.8	77.2	98	Off	Open	No
-4.8	Complete	4,992	62 [100]	76.8	77.2	98	Off	Open	No
-4.7	Complete	5,024	63 [101]	76.4	77.2	97	Off	Open	No
-4.6	Complete	5,024	63 [102]	76.4	77.2	98	Off	Open	No
-4.5	Complete	5,056	63 [102]	76.0	77.2	98	Off	Open	No
-4.4	Complete	5,088	64 [103]	76.4	77.2	98	Off	Open	No
-4.3	Complete	5,120	64 [103]	76.4	77.2	98	Off	Open	No
-4.2	Complete	5,120	65 [104]	76.4	77.2	98	Off	Open	No
-4.1	Complete	5,152	65 [104]	76.4	77.2	99	Off	Open	No
-4.0	Complete	5,184	65 [105]	76.4	77.2	97	Off	Open	No
-3.9	Complete	5,216	65 [105]	76.4	77.2	98	Off	Open	No
-3.8	Complete	5,216	66 [106]	76.4	76.4	76.4	Off	Open	No
-3.7	Complete	5,248	66 [106]	76.4	76.4	76.4	Off	Open	No
-3.6	Complete	5,248	66 [107]	76.4	76.4	76.4	Off	Open	No
-3.5	Complete	5,312	67 [108]	76.4	76.4	76.4	Off	Open	No
-3.4	Complete	5,376	67 [108]	76.4	76.4	76.4	Off	Open	No
-3.3	Complete	5,312	67 [108]	76.4	76.4	76.4	Off	Open	No
-3.2	Complete	5,344	68 [109]	76.4	76.4	76.4	Off	Open	No
-3.1	Complete	5,376	68 [109]	76.4	76.4	76.4	Off	Open	No
-3.0	Complete	5,408	68 [110]	76.4	76.4	76.4	Off	Open	No
-2.9	Complete	5,408	68 [110]	76.4	76.4	76.4	Off	Open	No
-2.8	Complete	5,440	69 [111]	76.4	76.4	76.4	Off	Open	Yes
-2.7	Complete	5,440	69 [111]	76.4	76.4	76.4	Off	Open	Yes
-2.6	Complete	5,472	70 [112]	76.8	77.2	98	Off	Open	Yes
-2.5	Complete	5,504	70 [112]	76.4	77.2	98	Off	Open	Yes
-2.4	Complete	5,504	70 [112]	76.4	77.2	98	Off	Open	Yes
-2.3	Complete	5,440	70 [113]	76.4	77.2	98	Off	Open	Yes
-2.2	Complete	5,408	70 [113]	76.4	77.2	98	Off	Open	Yes
-2.1	Complete	5,376	70 [113]	76.4	77.2	98	Off	Open	Yes
-2.0	Complete	5,344	69 [111]	76.4	77.2	98	Off	Open	Yes
-1.9	Complete	5,344	69 [111]	76.4	77.2	98	Off	Open	Yes
-1.8	Complete	5,280	68 [109]	76.4	77.2	98	Off	Open	Yes
-1.7	Complete	5,280	68 [109]	76.4	77.2	98	Off	Open	Yes
-1.6	Complete	5,120	66 [106]	76.4	77.2	98	Off	Open	Yes
-1.5	Complete	5,120	66 [106]	76.4	77.2	98	Off	Open	Yes
-1.4	Complete	4,960	64 [103]	76.4	77.2	98	Off	Open	Yes
-1.3	Complete	4,800	62 [100]	76.4	77.2	98	Off	Open	Yes
-1.2	Complete	4,800	62 [100]	76.4	77.2	98	Off	Open	Yes
-1.1	Complete	4,640	60 [97]	76.4	77.2	98	Off	Open	Yes
-1.0	Complete	4,640	60 [97]	76.4	77.2	98	Off	Open	Yes
-0.9	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.8	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.7	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.6	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.5	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.4	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.3	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.2	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
-0.1	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes
0.0	Complete	4,480	58 [94]	76.4	77.2	98	Off	Open	Yes

brake applied

t = -1.7 sec

Driver 2's PRT = $3.5 - 1.7 = 1.8$ sec

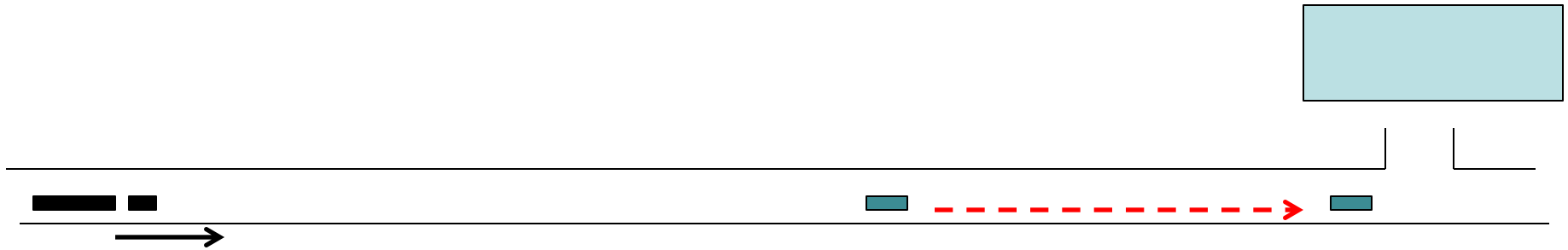
Accelerated motions:
non-constant speed

These calculations will include the rate at which the speed was changing, called acceleration.

The units of acceleration
are $\frac{\text{ft/sec}}{\text{sec}}$ or ft/sec^2

People of NY v. Munise

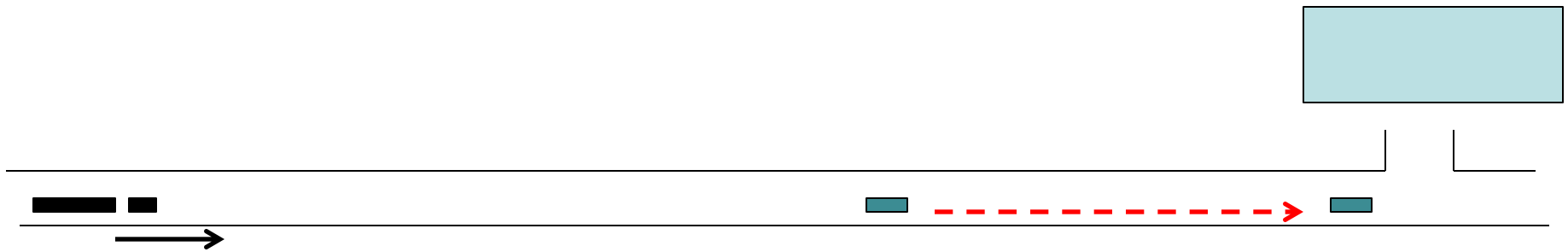
NYSP Trooper killed



State's theory: driver inattention
(cell phone) caused crash.

People of NY v. Munise

NYSP Trooper killed



Defense theory: Automatic alert system
in truck malfunctioned.

Making an assumption in one part of the analysis often creates a problem somewhere else.

Using the expert's assumptions to construct a request for a concession.

BRAKING TIME

$$t = (V - V_o) / 32.2 f$$

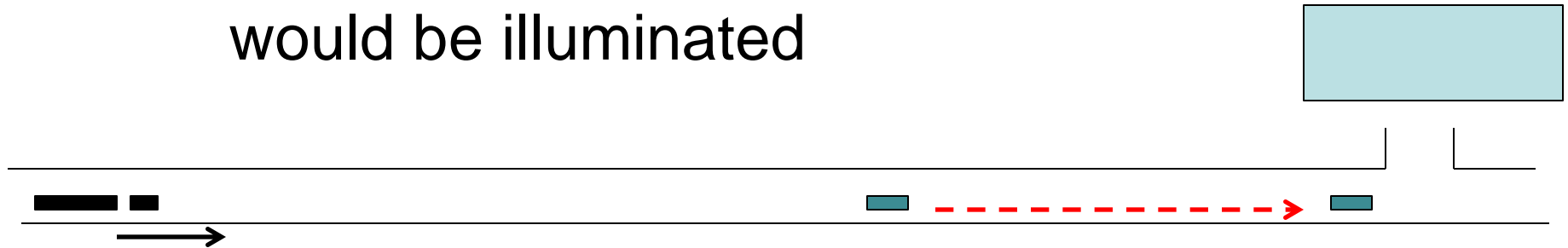
time for vehicle to brake from
one speed to another

People of NY v. Munise: NYSP Trooper killed

Δ expert opines about victim's speed(s)

Δ expert assumes a slowing rate for victim's car

State calculates the time the brake lights
would be illuminated



State asks Δ expert for a concession:

Based on the numbers in your own report
the time the defendant had to start an evasive
action was at least 13 seconds, correct?

*Acceleration after
traversing a curve*

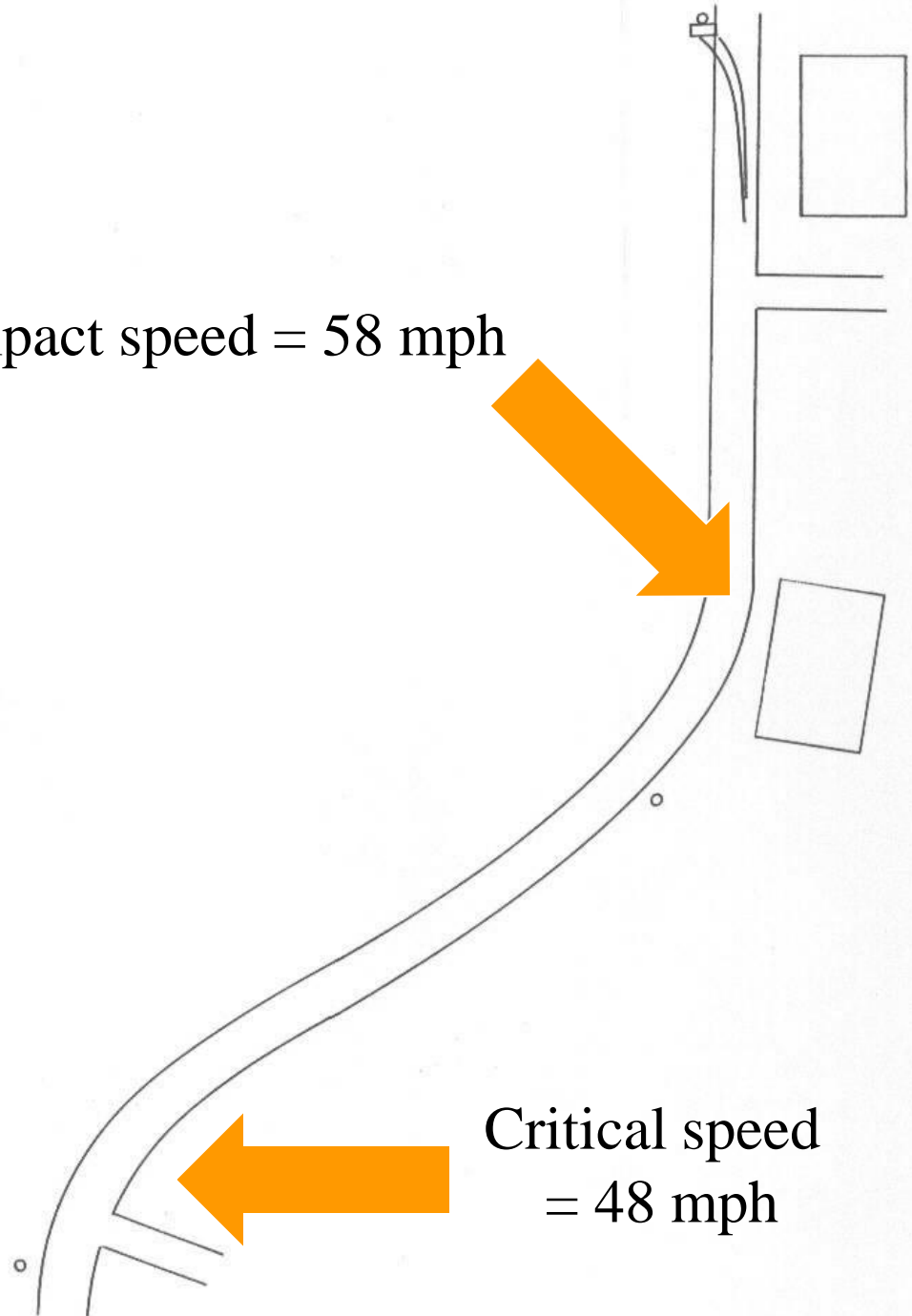
What is the critical speed
of a curve?

How is the critical speed
determined?

Impact speed
calculated to
be 58 mph

Impact speed = 58 mph

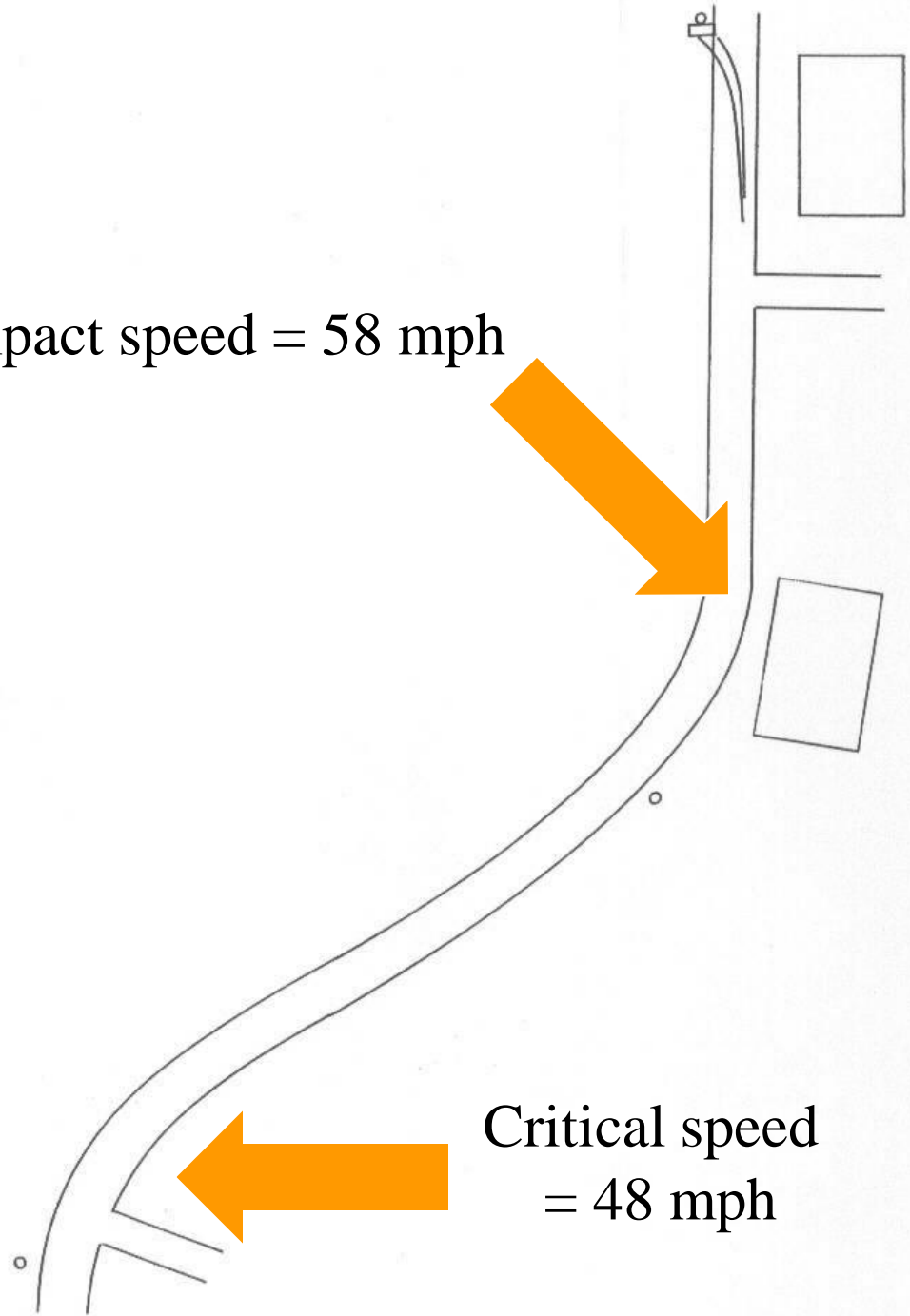
Critical speed
= 48 mph



Critical speed
in prior curve
was
determined.

Impact speed = 58 mph

Critical speed
= 48 mph



Could the vehicle traverse the
prior curve at a speed of 48 mph
and accelerate to a speed of
58 mph?

Accelerated motion:

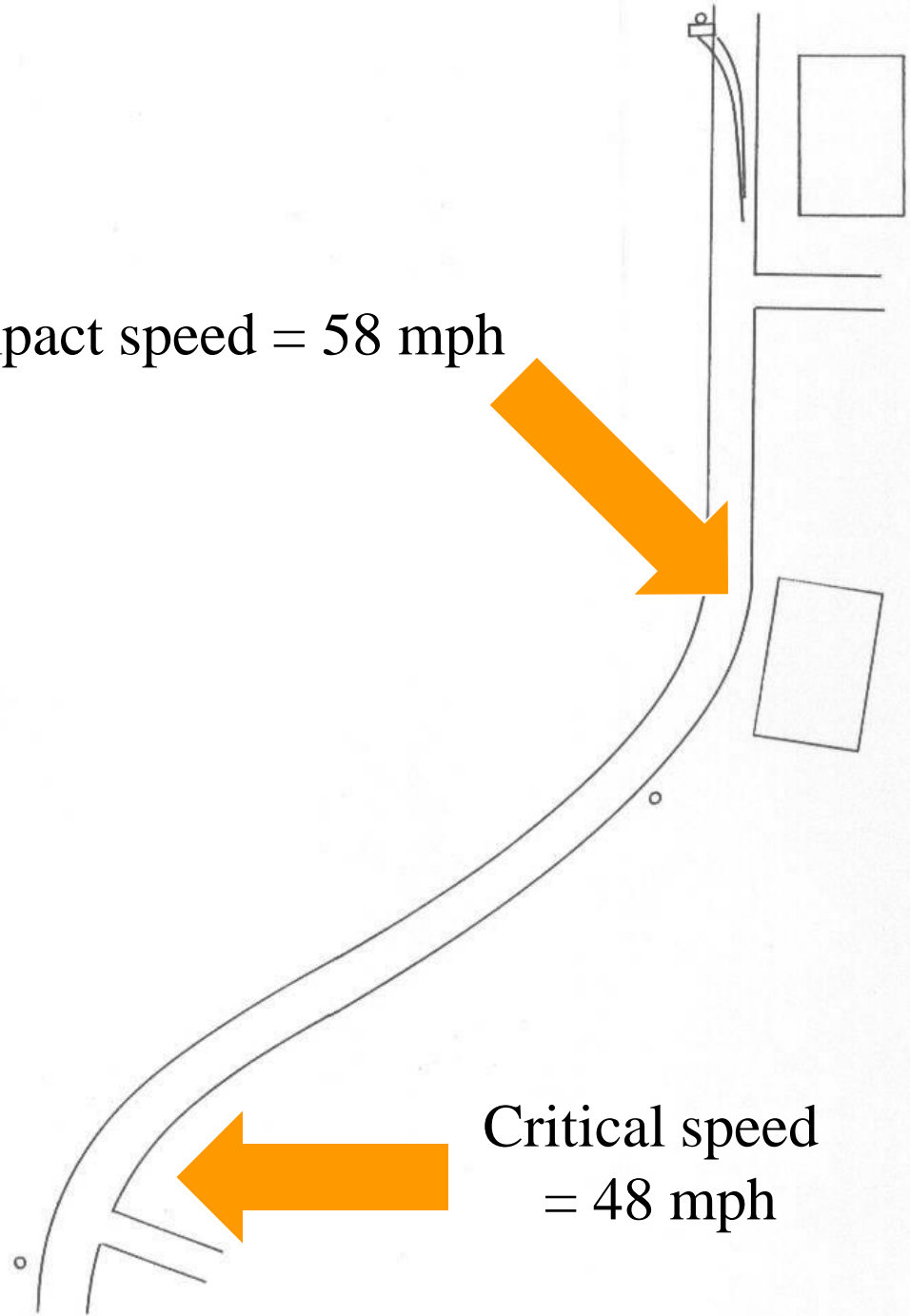
Speed at any distance
after start of acceleration:

$$v = \sqrt{v_o^2 + 2ad}$$

What information is needed to calculate the maximum possible speed at impact?

Impact speed = 58 mph

Critical speed = 48 mph



$$\mathbf{V_{max}} = \sqrt{(\mathbf{V_o}^2 + 2\mathbf{ad})}$$

$$V_o = 48(1.47) \text{ ft/sec}$$

$$a = 7.8 \text{ ft/sec/sec} *$$

$$d = 320 \text{ ft} \quad * \text{ Auto Stats}$$

$$\mathbf{V_{max} = \sqrt{(V_o^2 + 2ad)}}$$

$$V_o = 48(1.47) \text{ ft/sec}$$

$$a = 7.8 \text{ ft/sec/sec} *$$

$$d = 320 \text{ ft} \quad * \text{ Auto Stats}$$

$$\mathbf{V_{max} = 67.9 \text{ mph}}$$

(reconstructed speed = 58 mph)

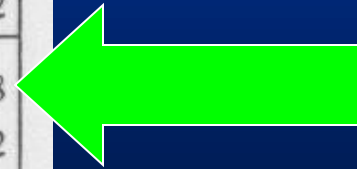
DID THE VEHICLE STOP
BEFORE ENTERING THE
INTERSECTION ?

SPEED AT POI WAS
DETERMINED TO BE 13 mph

A car has different possible
acceleration rates ?

To determine the maximum speed that could be reached, the maximum acceleration rate should be used in this calculation.

Condition	Speed range	Acceleration, a		
		Drag factor $f = a/g$	Meters per sec^2	Feet per sec^2
Free fall		+ 1.00	+ 9.81	+ 32.2
Normal acceleration of passenger car	Less than 20 mph (30kph)	+ 0.15	+ 1.47	+ 4.8
	20 to 40 mph (30 – 60 kph)	+ 0.10	+ 0.98	+ 3.2
	More than 40 mph (60kph)	+ 0.05	+ 0.48	+ 1.6
Rapid acceleration of passenger car	Less than 20 mph (30kph)	+ 0.30	+ 2.94	+ 9.7
	20 to 40 mph (30 – 60 kph)	+ 0.15	+ 1.47	+ 4.8
	More than 40 mph (60kph)	+ 0.10	+ 0.98	+ 3.2



“Using an accepted acceleration, the speed could not be reached if the defendant had stopped !”

EXPERT TESTIMONY:

“The operator did not stop prior to entering the intersection.”


SPEC SHEET FOR DEFENDANT'S VEHICLE

ACCELERATION:

0->30 mph $t = 3.8 \text{ sec.}$ $a = 11.6 \text{ ft/sec/sec}$ G-force = 0.36
0->60 mph $t = 9.8 \text{ sec.}$ $a = 9.0 \text{ ft/sec/sec}$ G-force = 0.28
45->65 mph $t = 5.9 \text{ sec.}$ $a = 3.7 \text{ ft/sec/sec}$ G-force = 0.12

SPEC SHEET FOR DEFENDANT'S VEHICLE

ACCELERATION:



0->30 mph	t = 3.8 sec.	a = 11.6 ft/sec/sec	G-force = 0.36
0->60 mph	t = 9.8 sec.	a = 9.0 ft/sec/sec	G-force = 0.28
45->65 mph	t = 5.9 sec.	a = 3.7 ft/sec/sec	G-force = 0.12

Using the maximum acceleration,
the speed attainable for MV #1,
if it stopped, is *16.9 mph*

Correct conclusion:

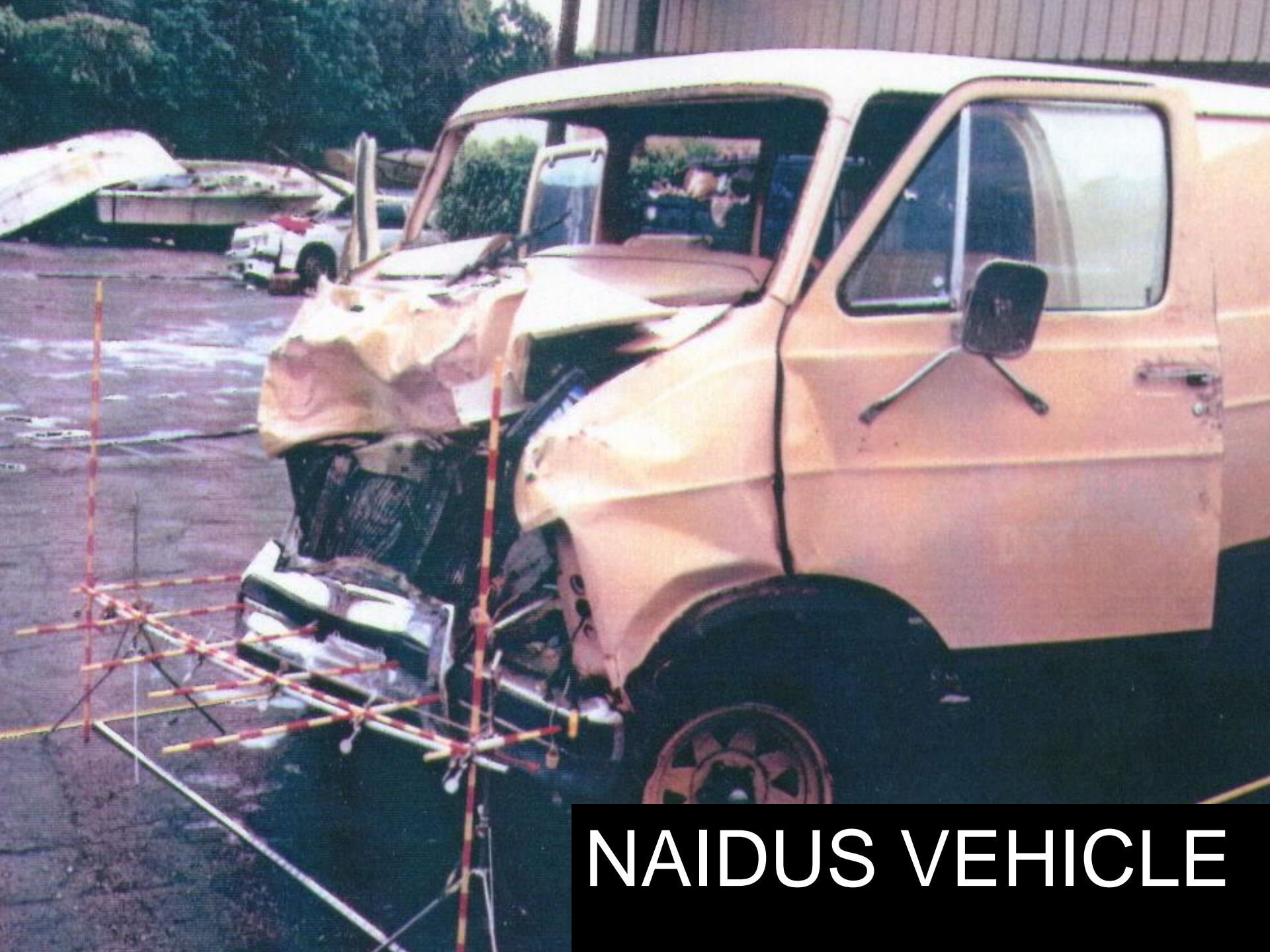
“It is inconclusive whether the vehicle stopped before entering the intersection.”

FL v. SCOTT NAIDUS

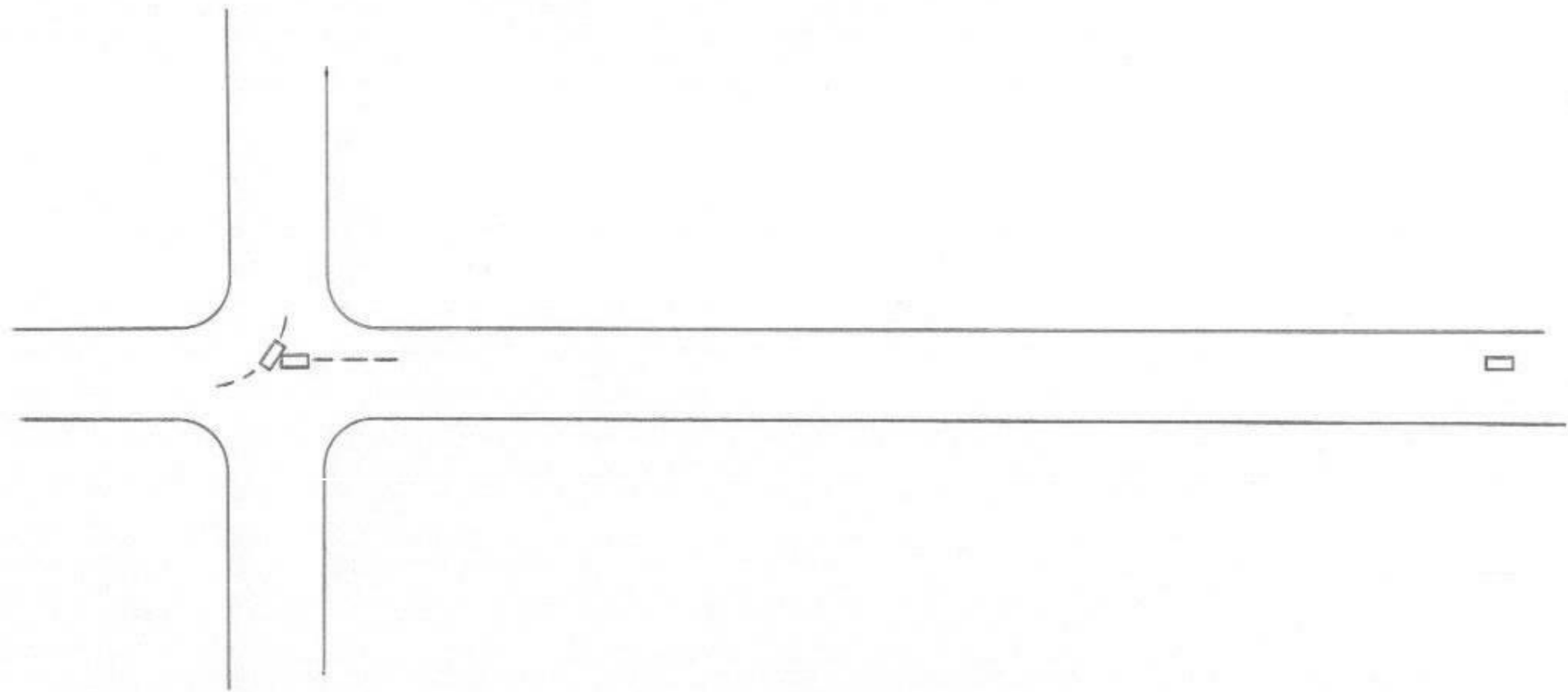
- VICTIM TURNS LEFT IN FRONT OF ONCOMING DEFENDANT
- NAIDUS CHARGED - DWI HOMICIDE
- ALEXANDER VEHICLE
 - MOTHER AND THREE CHILDREN KILLED



VICTIM'S VEHICLE



NAIDUS VEHICLE



CROSS EXAMINING THE DEFENSE ANIMATION

SOMETIMES THE DEFENSE
EXPERT DOES THE PROSECUTOR
A FAVOR BY GENERATING A
VIDEO ANIMATION

DEFENSE ANIMATION

A diagram of a T-junction intersection. A vertical road on the left meets a horizontal road on the right. A dashed line indicates the path of a vehicle entering from the left. A small square represents the vehicle at the intersection. Another small square is located further down the horizontal road on the right.

DEFENDANT VEHICLE SPEED = 55 MPH
VICTIM VEHICLE SPEED = 15 MPH

DEFENSE ANIMATION STARTS
9.5 SECONDS PRIOR TO IMPACT

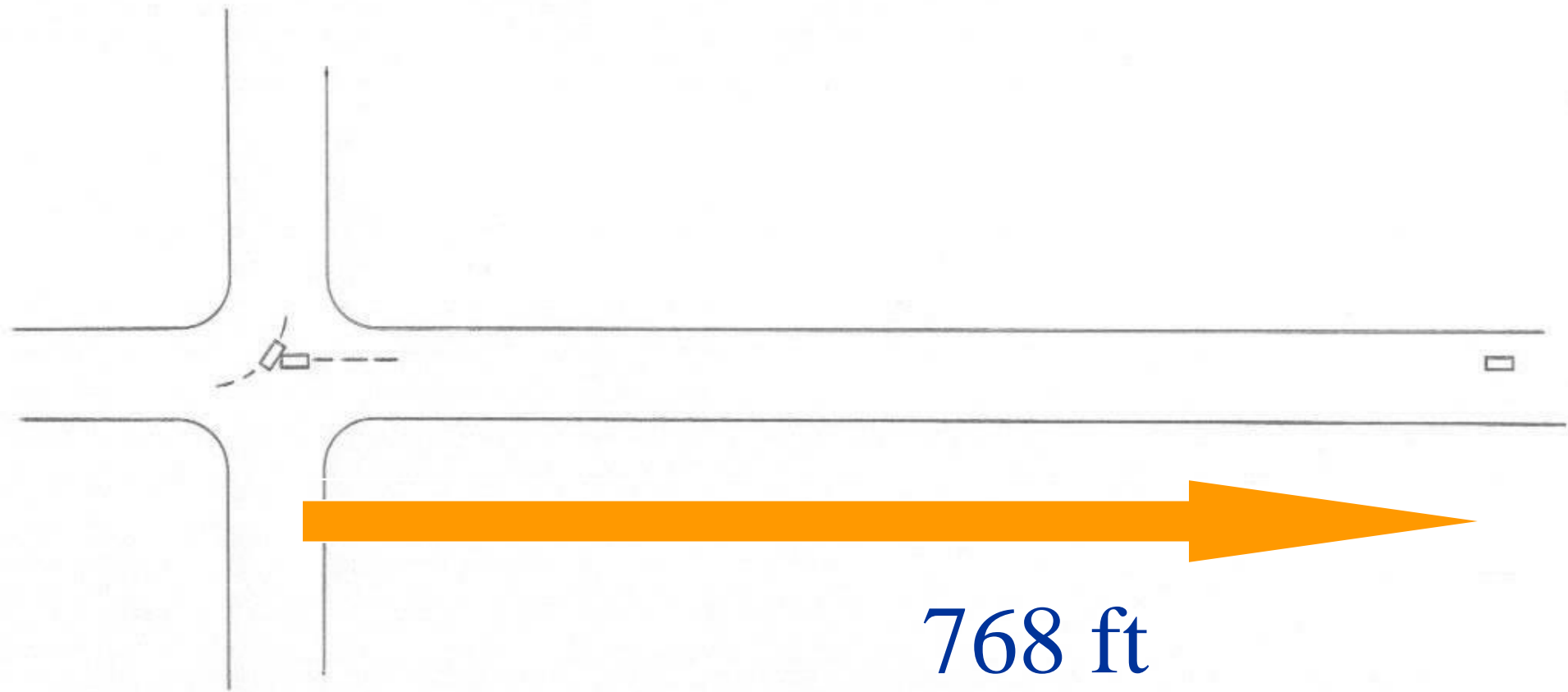
Locking the expert in :

- Speed of Naidus vehicle at all times
- Time from start of video to POI
- Lack of pre-impact braking
- Speed of turning vehicle
- Posted speed
- Naidus' ability to control speed
- No mechanical defect

*Using the defense expert's
animation to prove negligence*

How far was defendant's vehicle from poi when animation starts ?

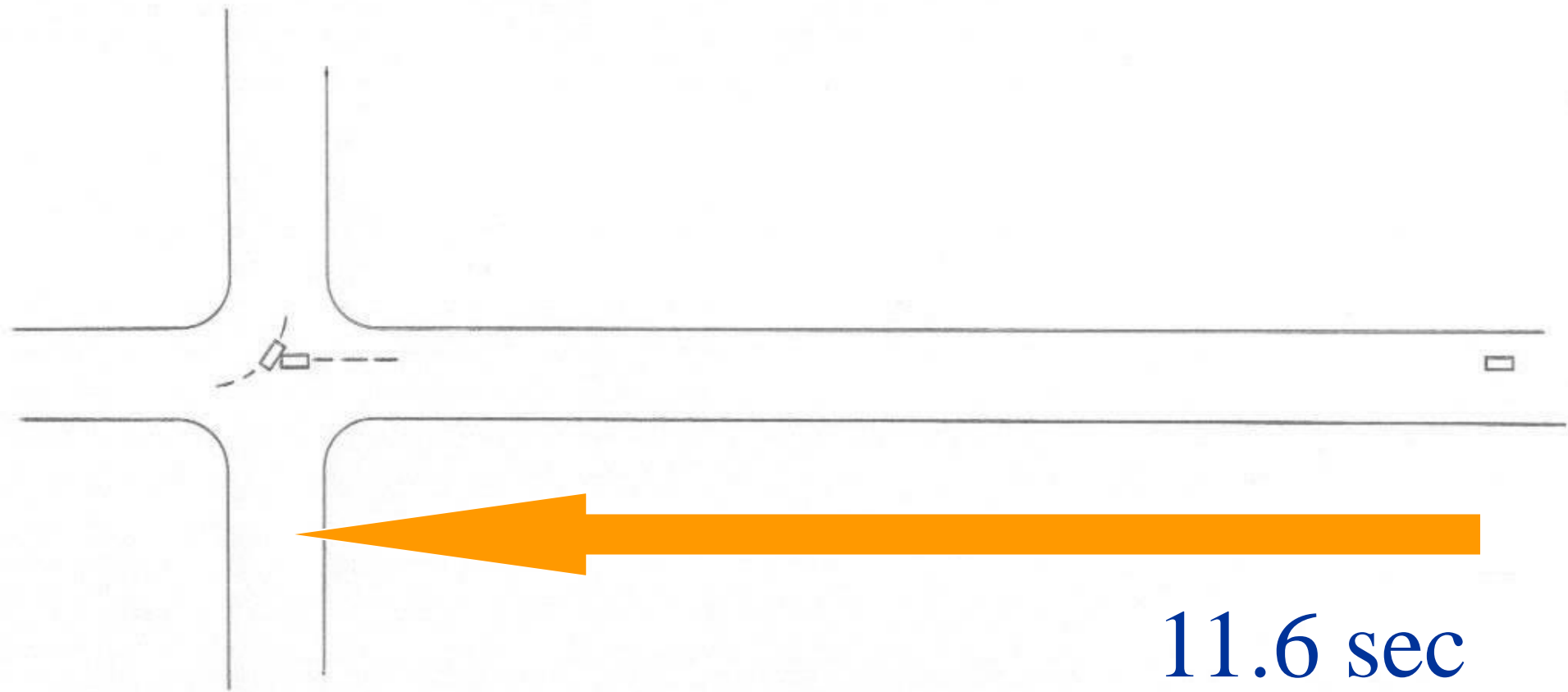
$$d = 1.47(55)(9.5) = 768 \text{ FT}$$



768 ft

If defendant were traveling at 45 mph (posted speed) rather than 55 mph how much time would it take defendant's vehicle to travel 768 ft ?

$$t = 768 / 1.47(45) = \mathbf{11.6 \text{ SECONDS}}$$



11.6 sec

If defendant were traveling at 45 mph (posted speed) rather than 55 mph he would have reached the POI 2.1 seconds later than he did.
Correct ?

YES

If defendant vehicle reached POI
2.1 seconds later, where would
victim's vehicle have been ?

$$d = 1.47(15)(2.1) = 46 \text{ ft}$$

CLEAR OF THE INTERSECTION

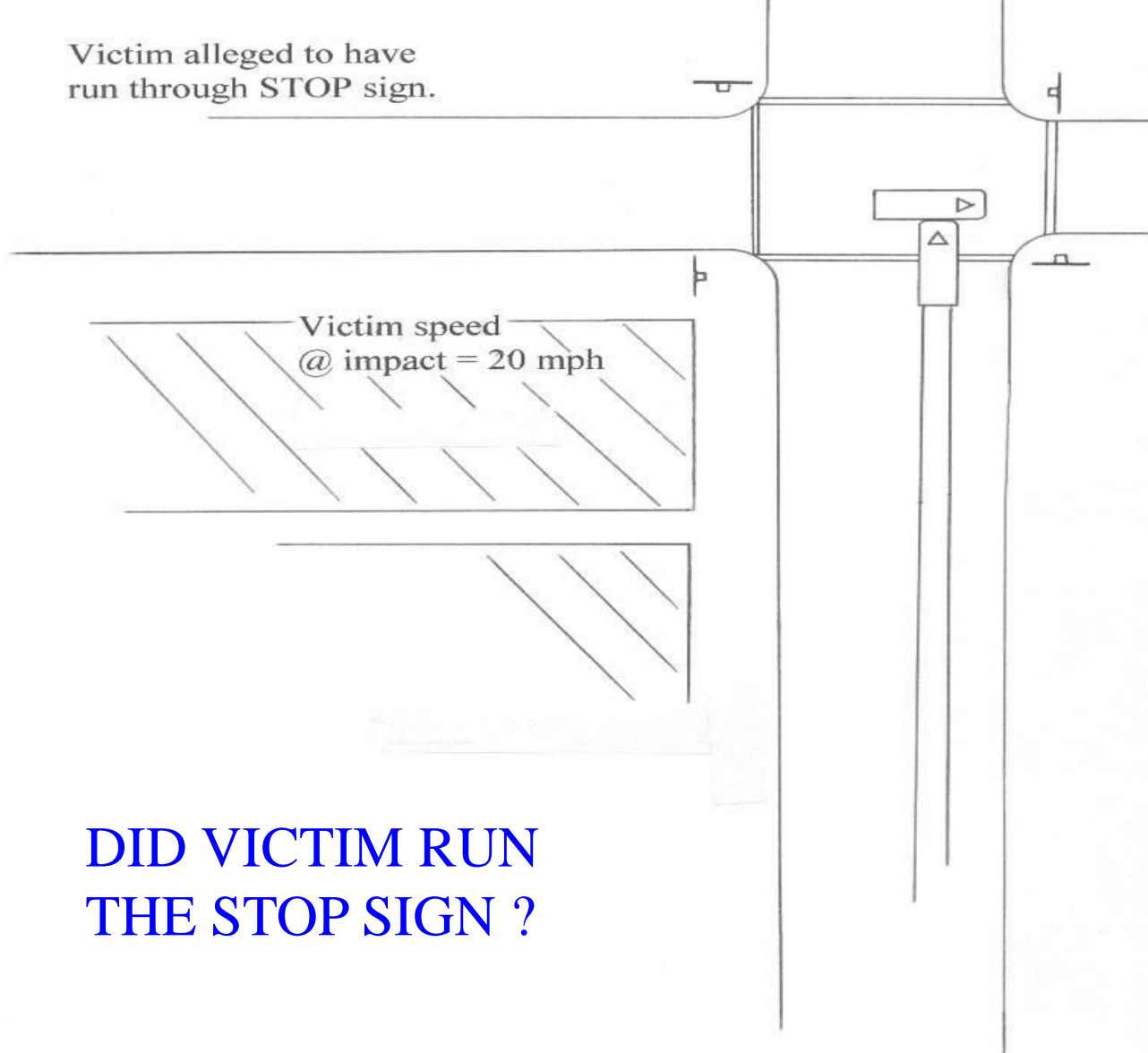
If defendant had been operating at the posted speed of 45 mph would there have been a crash ?

NO

Intersection collision,
Manchester, NH

*Defendant asserts that the victim
ran the stop and caused the crash.*

Victim alleged to have
run through STOP sign.

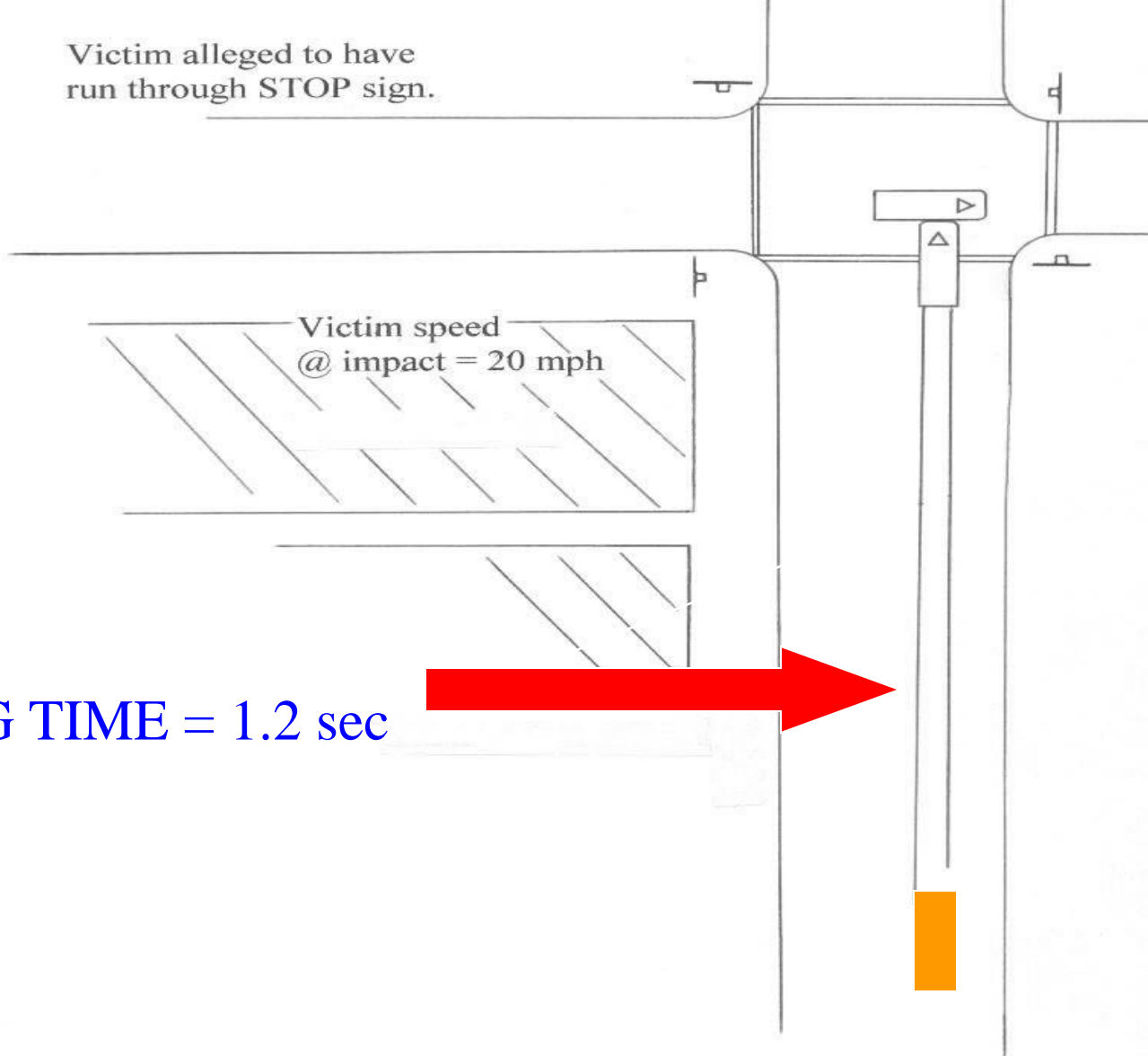
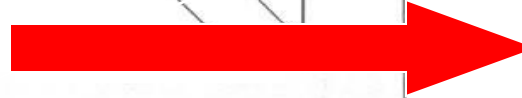


**DID VICTIM RUN
THE STOP SIGN ?**

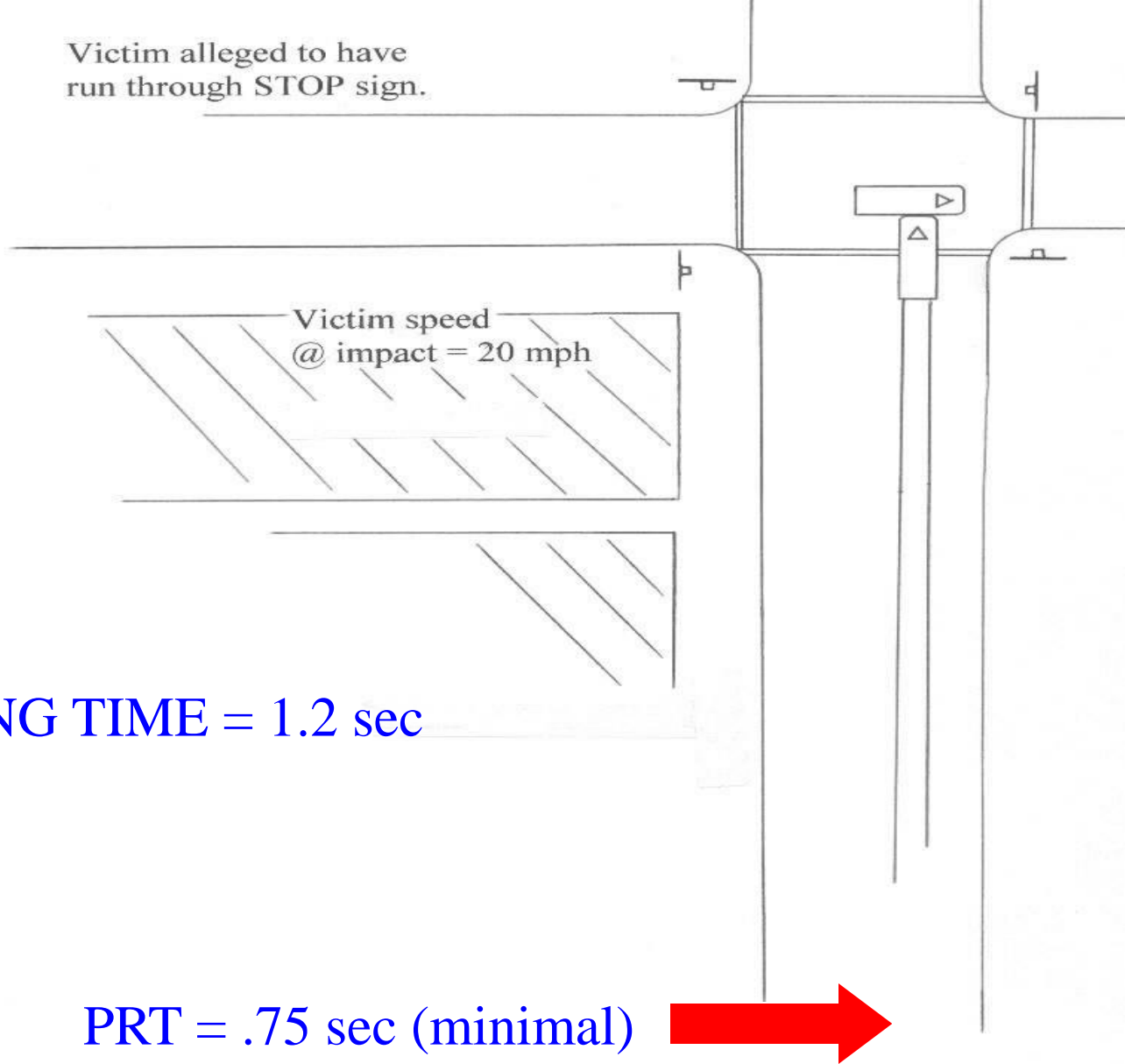
Victim alleged to have run through STOP sign.

Victim speed @ impact = 20 mph

BRAKING TIME = 1.2 sec



Victim alleged to have run through STOP sign.

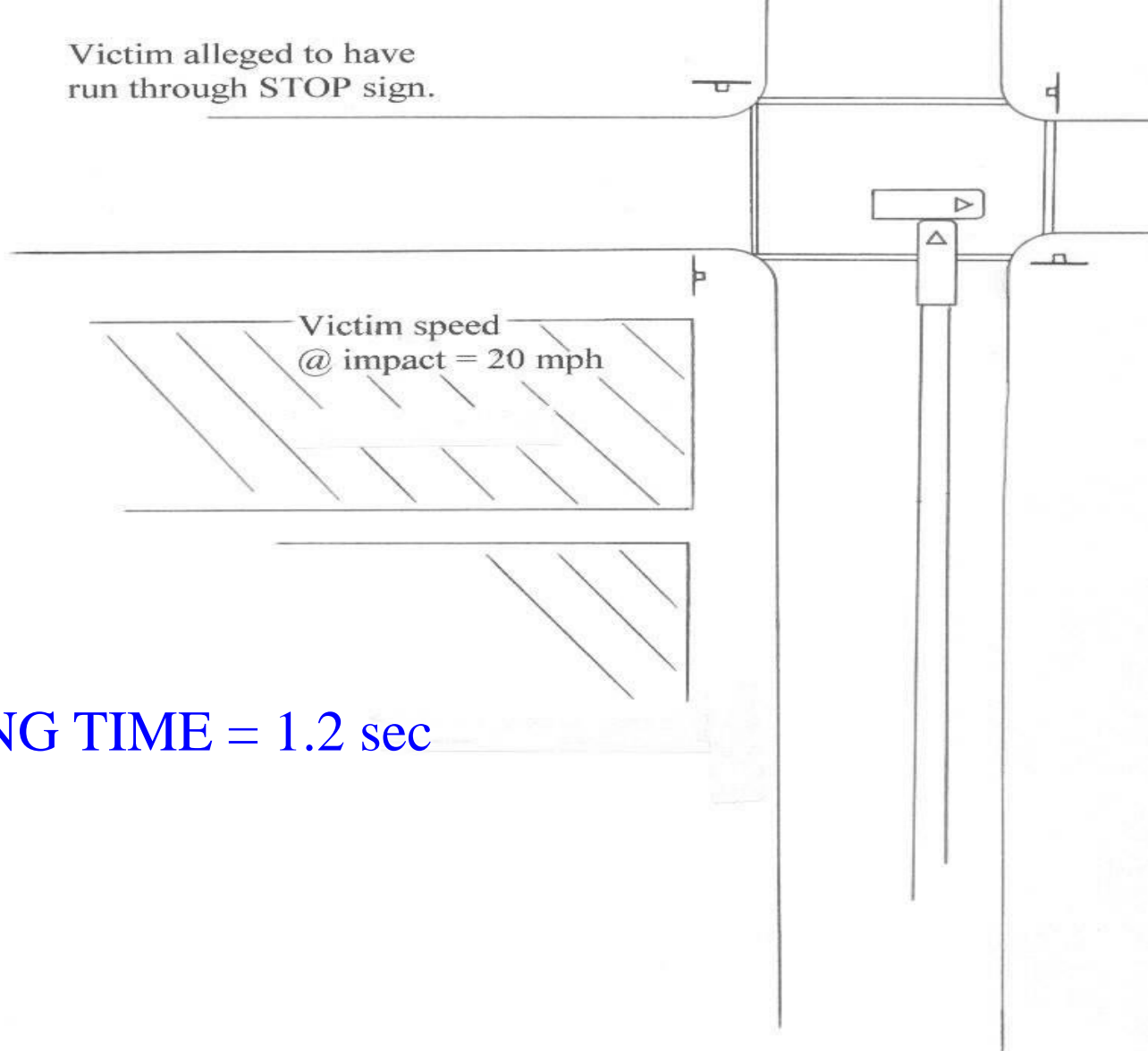


BRAKING TIME = 1.2 sec

PRT = .75 sec (minimal)



Victim alleged to have run through STOP sign.

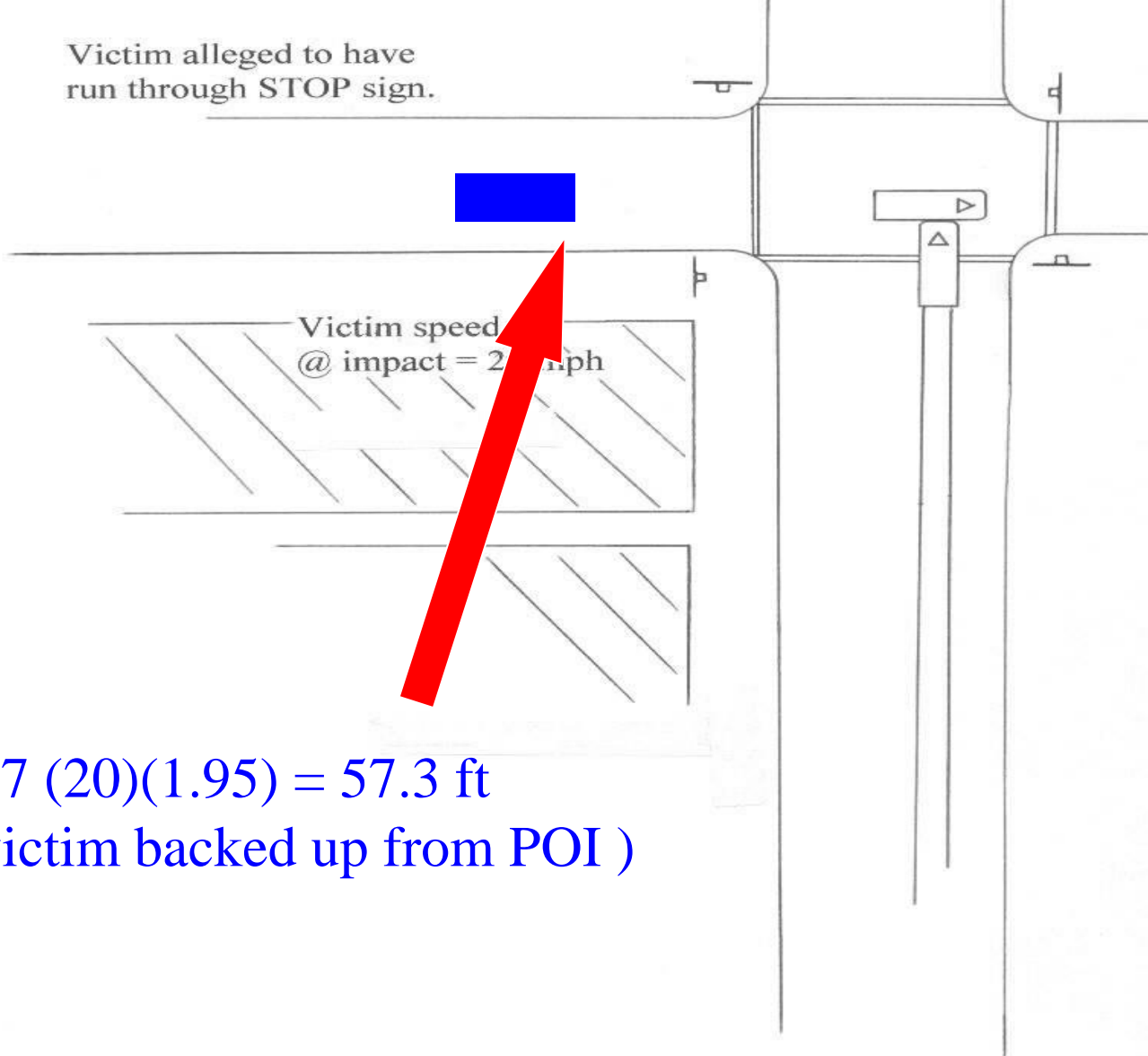


BRAKING TIME = 1.2 sec

defendant at start of PRT



Victim alleged to have run through STOP sign.



$$d = 1.47 (20)(1.95) = 57.3 \text{ ft}$$

(victim backed up from POI)



TDS checklist

Can you defend any *assumptions* ?

starting point for accelerated motion

acceleration rate

operator behavior

pedestrian walking speed

Was a range of values used ?

TDS checklist

Have human factors been considered ?

Visibility or conspicuity issues ?

PRT value – was a range of values used ?

Can TDS be used to develop additional facts ?

Is a hypothetical useful ?