National Transportation Safety Board

Office of Highway Safety

Washington, DC 20594

RPH24MR002

SIGNAL AND TRAIN CONTROL

Group Chair's Factual Report

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).

TABLE OF CONTENTS

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).

A. CRASH

Location: Chicago, Illinois
Date: November 16, 2023
Time: 10:31 a.m. (local time)
Train: CTA Yellow-line Train 593
Vehicle: CTA Rail Borne Snow Removal Vehicle S-500
Injury: 7 CTA employees and 16 train passengers

B. SIGNAL AND TRAIN CONTROL GROUP

Group Chair — Greg Scott, Chair
Rail Accident Investigator
NTSB - RPH

Group Member — James Harper
Chief Engineer Infrastructure
Chicago Transit Authority

C. ACCIDENT SYNOPSIS

On November 16, 2023, at about 10:31 a.m. (local time), a Chicago Transit Authority (CTA) Yellow Line Train No. 593 traveling on the southbound track collided with a Snow Removal Vehicle S-500 in Chicago, Illinois. The collision occurred as the CTA train was traversing through the Howard Yard enroute to the Howard Avenue station. As a result of the collision, the CTA train derailed. Six CTA employees occupied the snow removal vehicle and one of the employees was ejected out of the vehicle during the impact. All the occupants sustained injury. An operator and thirty passengers occupied the CTA train. Post-accident, the operator's cab of the train sustained extensive intrusion damage resulting from the impact with the snow removal vehicle. The operator was initially pinned in the compartment but was able to extricate himself, sustaining serious injury in the process. In addition to the train

operator, sixteen passengers were injured, sustaining a variety of injuries that ranged from minor to serious.

D. LOCATION DISCRIPTION

1.0 Chicago Transit Authority

1.1 Yellow Line Characteristics

The Yellow line extends from Dempster-Skokie to Howard in a timetable North-South direction. The line consists of double main track. Maximum authorized speed is 55 mph for transit trains.

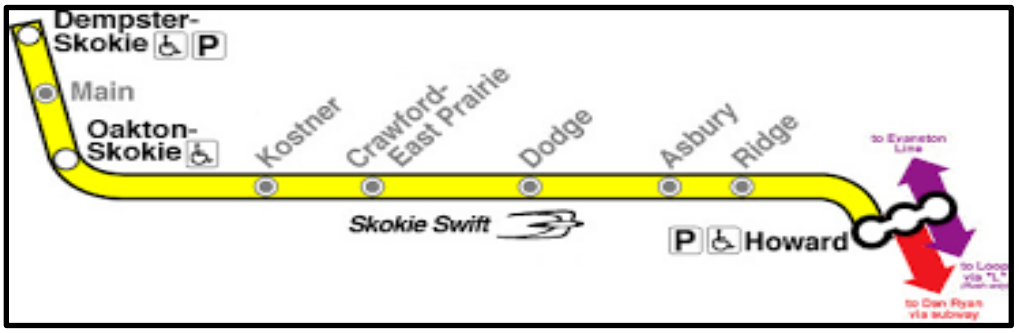


Figure 1: Map of CTA Yellow Line

1.2 Description of Signal System -Automatic Train Control (ATC)

The Chicago Transit Authority (CTA) system operates under an Automatic Train Control (ATC) system that was designed to allow for trains to be operated by a train operator while continuously protecting against hazards associated with trains, curves or signals ahead that the operator may not otherwise react to in a timely fashion. Designed during the introduction of signals to the CTA system in the early 1970s, that system, or its primary elements, remains in use today in many locations throughout the CTA rail network.

1.2.1 ATC Subsystem

Automatic Train Protection (ATP). The ATP subsystem is a wayside, meaning along the rail, system designed to provide protection against collision and train overspeed through the automatic block signaling system.

The ATP subsystem maintains train separation by transmitting speed commands to each train based on the instantaneous track occupancy conditions (i.e. presence of another train or railborne vehicle) ahead of the train (in the direction of travel), on the civil speed constraints (e.g. curves) ahead of the train, and on the status of any interlockings ahead of the train. The ATP system breaks the track down into a series of "blocks" that typically range in length from 500 feet to 2000 feet (only one train can occupy a block at any time). Each block is bounded by an impedance bond that is connected to the two running rails. A train is detected in the block when the train shunts the two rails with its wheels, interrupting a signal injected into the rails by the bond. The train detection system signals and the train speed command signals are generated at a nearby signal bungalow and are sent to the trains via two coded audio frequency signals (one signal for train detection and one for speed commands) injected into the track through the bonds delineating each block. . The speed commands are locally generated in the signal bungalow, are not relayed to the Operations Control Center (OCC), and cannot be modified by the OCC. The ATC system was designed never to allow trains to exceed the ATP speed command in normal operation.

1.2.2 Speed Commands

The electronic and electrical components necessary to implement the ATP subsystem are mounted on racks in signal bungalows located at various locations along the railway. Each signal bungalow contains the electronics associated with the track circuits monitored and controlled from that location.

Figure 2: Signal bungalow on left and equipment rack on right.

Speed commands sent by the ATC system are displayed on train operators' consoles. Each operator console displays the allowable cab speed.

1.2.3 Train Operating Modes

The degree of automation under which CTA trains operate is partially determined through the use of the following operating modes:

Manual with speed protection: Train acceleration and braking are manually controlled by the train operator, with overspeed protection provided by the ATP subsystem. The cab speeds of CTA trains are fixed at 0 mph, 15 mph, 25 mph, 35 mph, and 55 mph. A loss of cab signal, a train exceeding the cab speed, or a downgrade in cab speed—which can take up to 4 seconds for the onboard automatic train control (ATC) system to recognize—will result in an audible alarm in the cab.

When the alarm is sounded, the train operator must apply brakes within 2.5 seconds or the train will automatically brake until the train is stopped.

If the ATC system determines that a train should stop, the ATP speed transmitted to that train will be 0 mph. By design, if a train does not receive speed commands for any reason, the ATP speeds will default to 0 mph as a fail-safe measure.

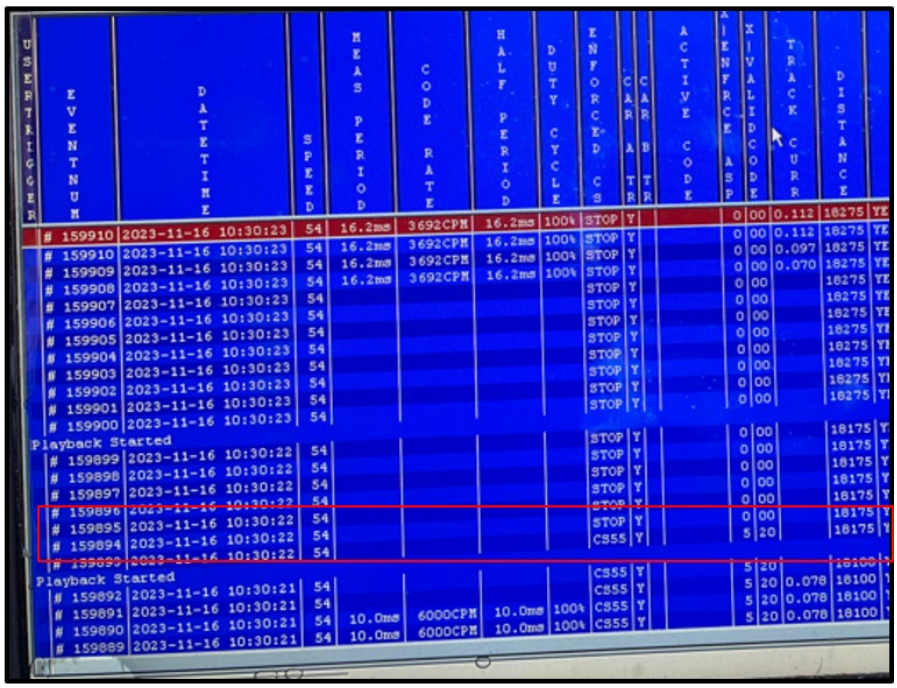
Manual with ATC cutout: All train operations are controlled by the operator, with no overspeed protection. This operating mode is only used when malfunctioning equipment makes Manual with speed protection unavailable or when the train must enter a block at restricting speed[1]

E. INVESTIGATIVE INFORMATION

2.0 Sequence of events

According to ATC downloads from the accident train, the train was traveling at 54mph with a 55mph cab code when it received a zero cab code at approximately 10:30:22.

[1] Restricting Speed: A speed that will permit stopping within one-half the range of vision. It will also permit stopping short of a train, a car, an obstruction, a stop signal, a derail, or an improperly lined switch. It must permit looking out for broken rail. It will not exceed 15 mph.

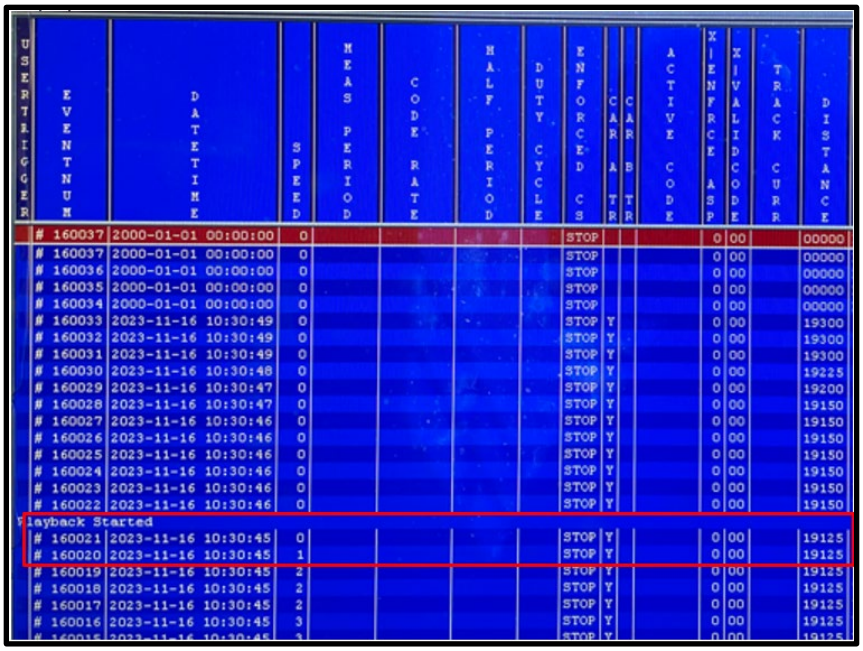


USERTRIGGER	EVENTNUM	DATETIME	SPEED	MEAS PERIOD	CODE RATE	HALF PERIOD	DUTY CYCLE	ENFORCED CS	CAB A TR	CAB B TR	ACTIVE CODE	AENFRCE ASP	XVALIDCODE	TRACK CURR	DISTANCE	
	# 159910	2023-11-16 10:30:23	54	16.2ms	3692CPM	16.2ms	100%	STOP	Y			0	00	0.112	18275	YE
	# 159910	2023-11-16 10:30:23	54	16.2ms	3692CPM	16.2ms	100%	STOP	Y			0	00	0.097	18275	YE
	# 159909	2023-11-16 10:30:23	54	16.2ms	3692CPM	16.2ms	100%	STOP	Y			0	00	0.070	18275	YE
	# 159908	2023-11-16 10:30:23	54	16.2ms	3692CPM	16.2ms	100%	STOP	Y			0	00		18275	YE
	# 159907	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159906	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159905	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159904	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159903	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159902	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159901	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
	# 159900	2023-11-16 10:30:23	54					STOP	Y			0	00		18275	YE
Playback Started																
	# 159899	2023-11-16 10:30:22	54					STOP	Y			0	00		18175	Y
	# 159898	2023-11-16 10:30:22	54					STOP	Y			0	00		18175	Y
	# 159897	2023-11-16 10:30:22	54					STOP	Y			0	00		18175	Y
	# 159896	2023-11-16 10:30:22	54					STOP	Y			0	00		18175	Y
	# 159895	2023-11-16 10:30:22	54					STOP	Y			0	00		18175	Y
	# 159894	2023-11-16 10:30:22	54					C355	Y			5	20		18175	Y
	# 159893	2023-11-16 10:30:22	54					C355	Y			5	20		18100	Y
Playback Started																
	# 159892	2023-11-16 10:30:21	54					C355	Y			5	20	0.078	18100	Y
	# 159891	2023-11-16 10:30:21	54					C355	Y			5	20	0.078	18100	Y
	# 159890	2023-11-16 10:30:21	54	10.0ms	6000CPM	10.0ms	100%	C355	Y			5	20	0.078	18100	Y
	# 159889	2023-11-16 10:30:21	54	10.0ms	6000CPM	10.0ms	100%	C355	Y			5	20	0.078	18100	Y

Figure 3: ATC download showing time cab code went from 55 to 0 (Stop)

The ATC download shows that when the operator received the 0 cab code he put the train into full service braking application at 10:30:23 and began braking for approximately 22 seconds till impact with the piece of equipment at 10:30:45.

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).



USERTRIGGER	EVENTNUM	DATETIME	SPEED	MEASPERIOD	CODERATE	HALFPERIOD	DUTYCYCLE	ENFORCEDCS	CARATR	CARBTR	ACTIVECODE	XINFRCEASP	XINVALIDCODE	TRACKCURR	DISTANCE
	# 160037	2000-01-01 00:00:00	0					STOP				0	00		00000
	# 160037	2000-01-01 00:00:00	0					STOP				0	00		00000
	# 160036	2000-01-01 00:00:00	0					STOP				0	00		00000
	# 160035	2000-01-01 00:00:00	0					STOP				0	00		00000
	# 160034	2000-01-01 00:00:00	0					STOP				0	00		00000
	# 160033	2023-11-16 10:30:49	0					STOP	Y			0	00		19300
	# 160032	2023-11-16 10:30:49	0					STOP	Y			0	00		19300
	# 160031	2023-11-16 10:30:49	0					STOP	Y			0	00		19300
	# 160030	2023-11-16 10:30:48	0					STOP	Y			0	00		19225
	# 160029	2023-11-16 10:30:47	0					STOP	Y			0	00		19200
	# 160028	2023-11-16 10:30:47	0					STOP	Y			0	00		19150
	# 160027	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
	# 160026	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
	# 160025	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
	# 160024	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
	# 160023	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
	# 160022	2023-11-16 10:30:46	0					STOP	Y			0	00		19150
Playback Started															
	# 160021	2023-11-16 10:30:45	0					STOP	Y			0	00		19125
	# 160020	2023-11-16 10:30:45	1					STOP	Y			0	00		19125
	# 160019	2023-11-16 10:30:45	2					STOP	Y			0	00		19125
	# 160018	2023-11-16 10:30:45	2					STOP	Y			0	00		19125
	# 160017	2023-11-16 10:30:45	2					STOP	Y			0	00		19125
	# 160016	2023-11-16 10:30:45	3					STOP	Y			0	00		19125

Figure 4: Shows time train went to zero mph (Time of impact)

The ATC download showed the train traveling approximately 1,125 feet from the time the operator received the zero cab code till the time the accident train came to rest after impact.

F. FIELD INVESTIGATION

3.0 Post Accident Investigation

3.1 Inspection Records

CTA signal maintenance test and inspection records were collected for the signal equipment at the accident area. The maintenance records indicate all circuit tests and inspections were conducted in accordance with CTA requirements.

3.2 Field Signal Testing

After review of the ATC download investigators began to focus on and verify the signal field equipment as the approximate distance of 1,125 feet during the incident as it did not match design. According to current field design the accident

train should have received the zero cab code approximately 2,148 feet prior to impact.

Field signal design for the accident train should have received a zero cab code on the 26, 15, and 9 track circuits. The signal design allowed 1,780 feet of stopping distance before arriving at the 9 circuit in which the equipment was occupying at the time of the accident.

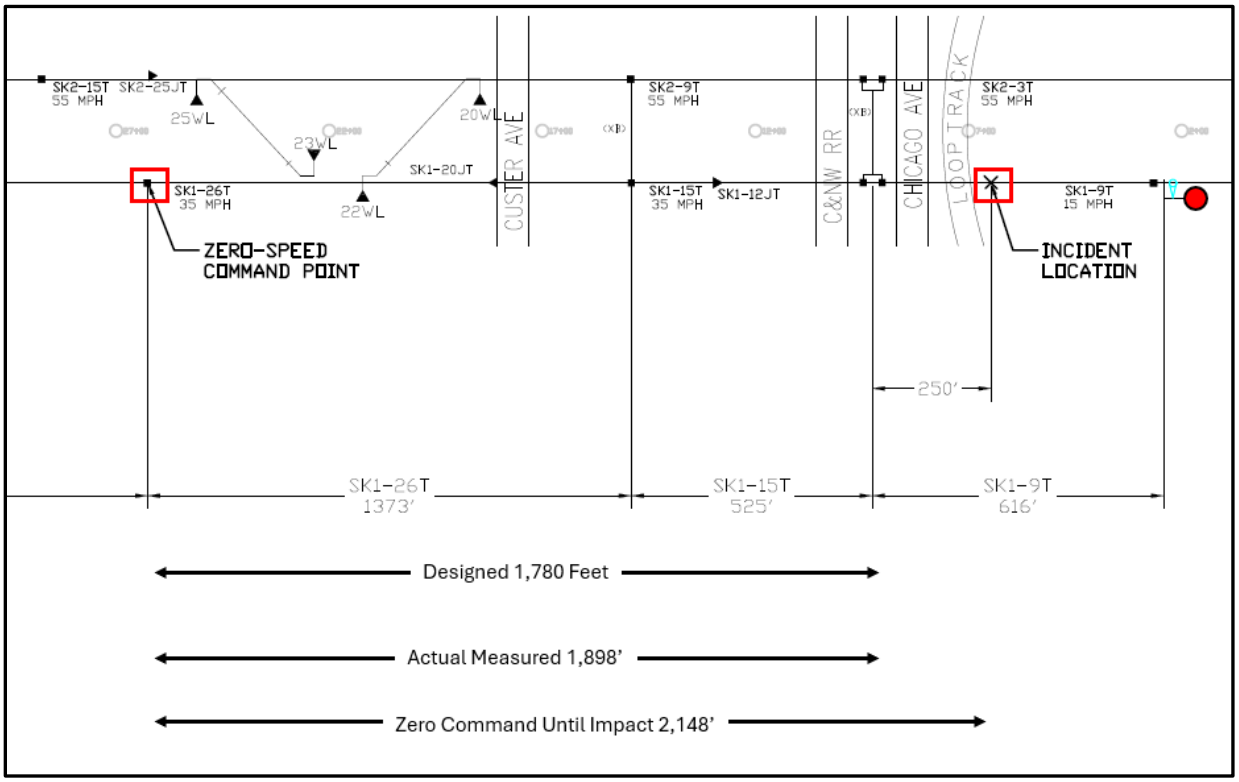


Figure 5: Diagram of signal design and impact distances

Investigators and CTA employees determined the accident train had at least received the 0 cab code on the 9 track circuit, the circuit the equipment was setting on, so the investigation began to verify the 26 and 15 circuits. CTA employees worked from the Asbury signal bungalow to verify the 26 and 15 cab circuit equipment.

All cab code equipment was tested on circuits in question, circuits 26 and 15. Circuits were tested for transmit and receive accuracy. All circuit tested per specification as below.

The ATP cab signal frequency shall be 4.55 kHz ± 90 Hz interrupted at:

- 50 cycles/min. (0.83 Hz) ± 4% for Restricted Speed (6mph adjustable up to 15mph)
- 75 cycles/min. (1.25 Hz) ± 4% for 15mph
- 120 cycles/min. (2.00 Hz) ± 4% for 25mph
- 180 cycles/min. (3.00 Hz) ± 4% for 35mph
- 270 cycles/min. (4.50 Hz) ± 4% for 55mph

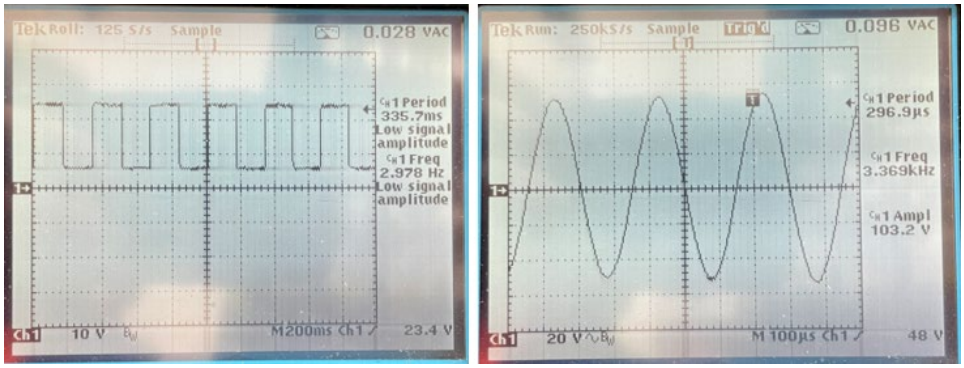


Figure 6: Oscilloscope examples of testing of cad code

Signal personnel simulated the train movements that occurred during the accident and all equipment performed as designed and transmitted the proper code to the proper circuits with no erroneous frequencies detected.

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).

3.3 Operator Account

During the accident train operators' interview, he mentioned after he received the zero cab code, and put the train into full service brake operations, he still did not feel as if the train was slowing as it should.

After the investigators reviewed the operators' comments, they began to realize the train wheels appeared to be slipping during the braking process and the recorder footage of 1,125 feet travel distance was not accurate.

Once investigators realized the recorder footage was inaccurate, they began to focus on the 22 seconds from 0 cab code until impact. Investigators then estimated the location the accident train received the 0 cab code by approximate feet per second to give them an approximate location that the accident train received the 0 cab code.

22 second x 80 foot per second (55mph) = Approximately 1,760 foot

After investigators determined the new approximate location that the accident train received the 0 code they determined that was in the area of the start of the 26 circuit, that the operator' should have received the zero code. Investigators then viewed the outward facing camera to the timestamp of 10:30:22 to verify that the accident train did in fact receive the zero cab code in the correct location, 26 circuit.

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).

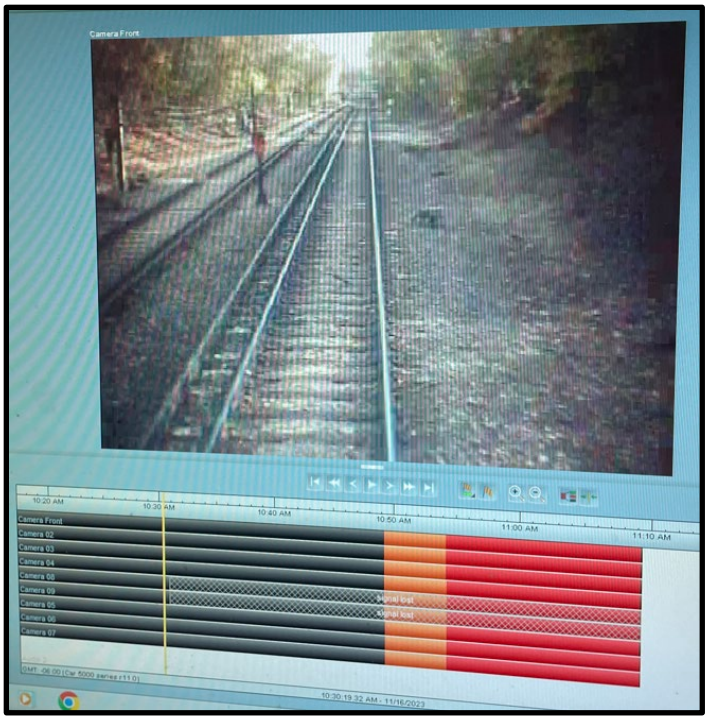


Figure 7: Outward facing camera view of location operator received 0 code.

4.0 Signal Braking Design

After investigators confirmed the Yellow Line train received the 0 code in the correct locations, they then reviewed the CTA signal design standards that allowed for proper braking distances. The investigations team reviewed the CTA Train Control Infrastructure Design Criteria Manual Section 11.15 ATP Safe Braking Distance Calculations and determined that the design was correct, and the train should have been able to stop in the designed 1,780 feet from where the train was traveling at 55mph and received the zero code until it entered the occupied circuit.

During the initial investigation it was mentioned that a new design allowed for 2,745 feet of stopping distance in the same situation. Investigators found that the new CAB circuit spacing distance was to allow for an 8 car consist in the future for an increase in passengers. The Yellow line currently runs a 2 car consist and this newer design distance did not apply in this location.

Investigators determined the signal system was working as currently designed and will be focusing on why the train was not able to stop in the designed distance.

5.0 Post Accident Actions

Even though the signal braking distances met the acceptable design criteria NTSB Investigators called into question the aggressive speed transition at the location of the incident, that is going from a 55mph to a zero mph. CTA completed an assessment of all track circuits on a system wide-basis, and identified four track circuits that were designed with a transition from 55 mph to zero mph, with no intermediate speeds:

1. EV1-643 on Evanston Purple Line Route (this line's train control system design was from same generation as the Yellow Line)
2. SK1-114T on Skokie Yellow Line Route
3. SK1-176T on Skokie Yellow Line Route
4. SK2-44T on Skokie Yellow Line Route (this was the track circuit involved in the approach to the downhill grade associated with the accident)

CTA temporarily mitigated these aggressive speed transitions by reducing the maximum allowable speed to 35 mph. They have completed design changes to each of these track circuits (by adding intermediate speeds), and they will be implementing the permanent changes in the upcoming weeks.

Submitted by:

G. Scott, Chair
Rail Accident Investigator
NTSB - RPH

This document contains preliminary information and may be subject to revision.
DISTRIBUTION OF THIS DOCUMENT IS RESTRICTED UNDER 49 CFR § 831.13 (B).