

Regional Transportation District



Final

R-Line Automatic Train Stop Plan (North of East Exposition Avenue/South Sable Boulevard)

June 16, 2023

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EXECUTIVE SUMMARY

On September 21, 2022, a Regional Transportation District's (RTD) light-rail vehicle derailed at the intersection crossing of East Exposition Avenue and South Sable Boulevard (Exposition/Sable) in the City of Aurora. This was the second derailment at this location, with the first occurring on January 28, 2019.

After the second derailment, RTD proposed to the Colorado Public Utilities Commission (CPUC) that several changes to the Exposition/Sable intersection be made, and these changes were approved by CPUC as part of a Corrective Action Plan. Proposed changes included *"to develop a formal plan for implementation of ATS to be installed north of the curve on A-Track. RTD proposes to file this plan by June 30, 2023."*

Automatic train stop (ATS) is a system that automatically stops a train to prevent accidents if certain situations occur (in this scenario - overspeed, where the travel time of a train through a block distance is faster than the preset timer).

This plan provides a general analysis of the condition at the Exposition/Sable intersection, evaluates the ATS devices that are currently used in the Automatic Block Signal (ABS) territories in the RTD light rail transit (LRT) system, and provides the analysis and plan to implement and install the ATS north of the curve of the A-Track approaching the Exposition/Sable intersection as a method of mitigating the risk of possible future derailment incidents at this location due to overspeeding.

A three-block/two-ATS-trip concept design is proposed to provide the overspeed train tripping function while allowing uninterrupted train operations for trains running under the speed of the speed limit signs. It should be noted that the concept of ATS differs from the concept of automatic train control (ATC) in that ATS does not feature an onboard speed monitor or speed control mechanism. The proposed ATS design will provide the following overspeed protection features:

- The first trip point would apply a mandatory brake for trains exceeding 25 miles per hour (mph) at a distance from the intersection sufficient to stop a 45-mph overspeed train prior to entering the track curve.
- The second trip point would apply a mandatory brake for trains exceeding 10 mph at a distance from the intersection sufficient to stop a 25-mph overspeed train prior to entering the track curve.
- Erratic operator behavior in ATS blocks such as slowing down or stopping and then accelerating through the trip points would reduce the effectiveness of the solution.

The estimated time to implement and install the ATS is approximately 1 year, and the estimated cost is approximately \$876,000.



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Exhibits (provided as separate files)

- Exhibit 1. ATS Layout North of the Exposition/Sable Intersection (proposed)
- Exhibit 2. Preliminary Hazard Analysis Report



Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ABS	automatic block signal
ATC	automatic train control
ATS	automatic train stop
CPUC	Colorado Public Utilities Commission
CS	curve-to-spine
Hz	hertz
IB	impedance bond
IJ	insulated joint
LRT	light rail transit
LRV	light rail vehicle
mph	miles per hour
mphps	miles per hour per second
RTD	Regional Transportation District
SC	spiral-to-curve
SIG	signal
TSP	transit signal priority



1 Introduction

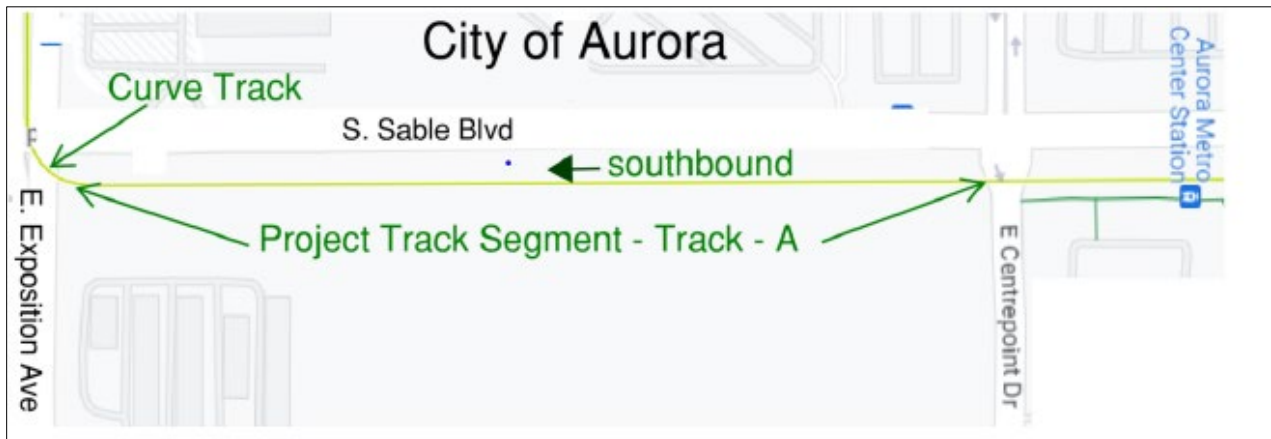
On September 21, 2022, a Regional Transportation District’s (RTD) light rail vehicle (LRV) derailed at the intersection crossing of East Exposition Avenue and South Sable Boulevard (Exposition/Sable) in the City of Aurora. This was the second derailment at this location, with the first occurring on January 28, 2019.

After the second derailment, RTD proposed to the Colorado Public Utilities Commission (CPUC) that several changes be made to the Exposition/Sable intersection, and these changes were approved as part of a Corrective Action Plan. Proposed changes included developing a formal plan to implement and install an automatic train stop (ATS) north of the curve on the A-Track. RTD intends to file this plan to the CPUC by June 30, 2023.

This ATS plan provides a general analysis of the conditions at the Exposition/Sable intersection, evaluates the ATS devices that are currently used in the automatic block signal (ABS) territories in the RTD light rail transit (LRT) system, and provides the analysis and plan to implement and install the ATS north of the curve of the A-Track approaching the Exposition/Sable intersection as a method of mitigating the risk of possible future derailment incidents at this location due to overspeeding.

This ATS plan and study is limited to the southbound train movement on the north of the track curve on the A-Track, between the Aurora Metro Center Station and north of the Exposition/Sable intersection. For this study, this piece of track is referred to as the “Project Track Segment” (see Figure 1-1).

Figure 1-1. Project General Layout





2 Existing Track Layout and Train Operations

The LRT system in the Project Track Segment area consists of two parallel tracks at street level, a southbound track (A-Track) and a northbound track (B-Track). The Project Track Segment is on the A-Track and is a tangent track in north-south direction. The south end of the Project Track Segment continues through the Exposition/Sable intersection where the track changes direction to the west on a nearly 90-degree-curve track that has a 10-mph train speed limit on the curve. The Project Track Segment has a +4.25 percent track grade southbound between East Centrepoint Drive crossing and north of the Exposition/Sable intersection. The Project Track Segment is part of the RTD R-line street-run territory, which has a general operation speed limit of 35 mph, except at locations where speed limit signs of lower speed are installed.

Table 2-1 and the subsequent key notes describe the existing track layout, traffic signals, and train operations (see Exhibit 1 for the full layout).

Table 2-1. Simplified Track Layout North of the Exposition/Sable Intersection

Key Note	Stationing	Descriptions
a	885+80	Metro Center Station South End, TSP-51, TSP-52
b	883+51	East Centerpoint Drive Bar-Signal, TSP-47, TSP-48, 25 mph SIGN
c	871+18	North Point of 10-mph Curve
d	870+90	Sable/Exposition, Bar-Signal, TSP-41, TSP-42, 10 mph SIGN

2.1 Key Note Descriptions

The following information describes the key notes of Table 2-1:

- a. RTD Aurora Metro Center Station: Under normal operation, the southbound train uses the A-track to enter the station from the north; the mode of operation is street-run, and the speed limit is 35 mph. The service train is required to stop at the south end of the station to release and pick up passengers. The transit signal priority (TSP) detection loops (TSP-51 and TSP-52) on the south end of station are used to provide the stop bar recall function when the loops detect a southbound train, the TSP function of the Centrepoint Drive traffic signal system will be initiated.
- b. East Centrepoint Drive crossing: When the train is ready to depart the Metro Center Station, the train operator observes the traffic system controlled LRV transit signal (bar-signal) located on the south side of the road. The train operator accelerates the train when the LRV transit-signal displays a “go” aspect. The train operator follows the street-run operation rules and observes the 25-mph speed limit sign mounted on the LRV transit signal. Currently, the TSP detection loops TSP-47 and TSP-48 on the south side of East Centrepoint Drive are not used and the TSP function on the southbound train at the Exposition/Sable intersection traffic signal system is disabled.
- c. Curve track at the Exposition/Sable intersection: This curve track is a compound curve and has a 10-mph design train speed limit. The 10-mph civil-design speed limit starts on the north end curve-to-spiral (CS) point at 871+18 and ends on the west end spiral-to-curve (SC) point at 870+06. The train operator observes the 10-mph speed limit sign (digital radar speed sign) that is placed in advance to the north of the curve point and the 10-mph signal mounted at the LRV transit signal and brakes the train to 10 mph prior to entering the curve.



- d. Exposition/Sable intersection LRV transit signal: A traffic system controlled LRV transit signal (bar-signal) is used to control the train movement through the intersection. If the signal displays a “stop” aspect, the train operator stops the train before the LRV transit signal. The TSP loops TSP-41 and TSP-42 at the location are used for the stop bar recall function. If the LRV transit signal displays a “go” aspect, the operator is allowed to operate the train at 10 mph through the intersection.



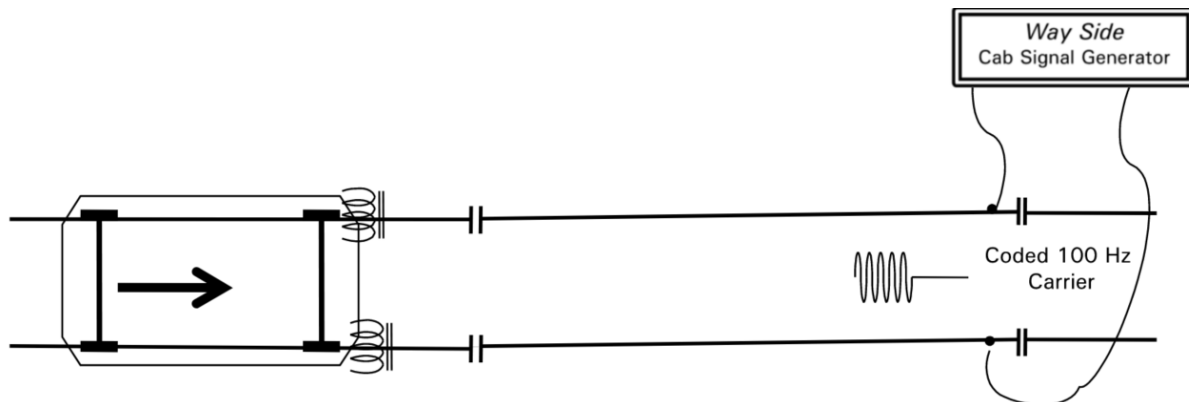
3 Automatic Train Stop

3.1 Automatic Train Stop Descriptions

The ATS consists of wayside devices installed on the equipment cases, track circuit connections to the track blocks, and onboard devices installed on the LRV train. Refer to Figure 3-1.

- Wayside ATS/cab signal generator and track circuits: This generator generates the 100 hertz (Hz) cab signal. The 100-Hz signal is turned ON and OFF to produce a coded signal. A 100-Hz signal turned ON and OFF 270, 180, or 75 times a minute is referred to as a 270, 180, or 75 Code. The cab signal is placed onto the track block through the track circuit cables. The track circuit devices also detect the presence or absence of the train in the track block.
- Track Block: the alignment is divided into blocks. The track in each block is electrically isolated from the preceding and following blocks by insulated joints (IJ). Impedance bonds (IB) are installed at IJ locations to bypass direct current traction power negative current flow on track.
- Onboard ATS/cab signal equipment: The pick-up coils are installed in the front end and under the car on both ends of the LRV. The front-end pick-up coils detect the 100-Hz current on the rail. When the onboard ATS equipment detects a 270 or 180 Code on the rail, the ATS on the LRV “arms” and LRV enters ATS mode. Once armed, whenever the 270 or 180 Code is lost, the ATS onboard equipment will set the mandatory brake and brings (trips) the LRV to stop. Detection of a 75 Code by onboard ATS equipment will cause the LRV to leave ATS mode. Note that the Onboard ATS/Cab Signal equipment is not connected to the train speedometer and does not monitor the actual train speed.

Figure 3-1. Typical ATS/Cab Signal and Track Block Layouts



3.2 Automatic Train Stop in RTD LRT Signaled Territory (existing)

The automatic block signal (ABS) and ATS are installed in LRT signaled territories. A 270 or 180 Code is placed on the block followed by a green or yellow signal, and a “No Code” is placed on the block followed by a red signal. If a train overruns a red signal, the onboard ATS device will detect a “No Code”, and trip and stop the train. All RTD LRVs are equipped with onboard ATS/Cab Signal equipment.

3.3 ATS in RTD LRT Street-Run Territory (proposed)

Currently, there are no wayside ATS devices installed in LRT street-run territories.



A new wayside ATS layout will be installed at the Project Track Segment to provide train overspeed protection function for the curve track at Exposition/Sable intersection.

The wayside ATS layout will include the following features:

- Relay cases to house the wayside ATS equipment
- Wayside track blocks/track circuits, ATS-signals, begin and end ATS signs, and speed limit signs
- ATS/Cab Code of 180, 75, and “No Code” will be used

Note: Change to LRV onboard ATS/Cab signal equipment is not needed.

3.3.1 Two-Block/One-ATS-Trip Layout Design

The concept is to use a timer and ATS codes so that if a train moves too fast in the track block and arrives too early at the ATS signal (tripping point), the onboard ATS equipment will trip and stop train (see Table 3-1).

Table 3-1. Two-Block/One-ATS-Trip Layout Design

	ATS SIG-A		
<i>Reference No.</i>	<i>Block-B</i>		<i>Block-A</i>
A1	No Code	No Train	No Code No Train
A2	No Code (Timer-A Countdown)		180 Code <<-Train
A3	75 Code (Timer-A =0"/Expired)		<<-Train
A3	75 Code (Timer-A =0"/Expired)	<< Train	No Code
A4	No Code (Timer-A >0)	<<	<-Train Trip To Stop

3.3.1.1 ATS Function Descriptions

The following information describes the ATS functions shown in Table 3-1:

- A1. Initially no train is in Block-A or Block-B, and “No Code” is placed on Block-A and Block-B.
- A2. When a train enters Block-A, the track circuit in Block-A detects the train and places 180 Code on Block-A. The train detects the 180 Code and the onboard ATS is “armed.” Timer-A starts counting down from the pre-set value.
- A3. If the train does not enter Block-B when Timer-A expires (timer=0), the “No Code” in Block-B is changed to 75 Code. This will allow a train running at, or slower than, the speed limit to continue moving from Block-A to Block-B without interruption. The 75 Code will turn off the onboard ATS function after the train enters Block-B.
- A4. However, if the train runs at a speed higher than the speed limit in Block-A, and Timer-A has not expired (timer >0 second) by the time the train enters Block-B, the train will receive a “No Code” and will be tripped to stop. The initial Timer-A setting is based on the length of Block-A, the expected train speed profile in Block-A, and the equipment reaction time. For example, the train runs at a constant speed of 25 mph in Block-A: Timer-A setting = run time (25 mph in Block-A) – equipment reaction time.



To avoid incorrectly tripping a train that runs at the speed limit (with a tolerance of 2 mph above the speed limit), the timer may be set at a lower setting to allow for smooth train operation. The setting of the timer value will be determined during the final design and be adjusted during the train runs testing.

3.3.2 Three-Block/Two-ATS-Trip Layout Design

Two-block/one-ATS-trip layout can be expanded to three-block/two-ATS-trip layout to provide overspeed tripping at two trip points. The operation principles of a three-block/two-ATS-trips layout is similar to the two-block/one-ATS-trip layout (see Table 3-2).

Table 3-2. Three-block/Two-ATS-Trips Layout Design

Reference No.	ATS SIG-B		ATS SIG-A	
	Block-C	Block-B	Block-B	Block-A
A1	No Code	No Train	No Code	No Train
A2	No Code	No Code (Timer-A Countdown)	180 Code	<<-Train
A3	75 Code	180 Code (Timer-A=0"/Expired)	<<-Train	
B2	No Code (Timer-B Countdown)	180 Code	<<-Train	No Code
B3	75 Code (Timer-B=0"/Expired)	<<-Train		No Code
B3	75 Code	<<-Train	No Code	No Code
A4	No Code	No Code (Timer-A>0)	<<	<<-Train Trip To Stop
B4	No Code (Timer-B>0)	<<	<<-Train Trip To Stop	No Code

3.3.2.1 ATS Function Descriptions

The following information describes the ATS functions shown in Table 3-2:

- A1. Initially no train is in Block-A, Block-B, or Block-C, and “No Code” is placed on Block-A, Block-B, and Block-C.
- A2. When a train enters Block-A, the track circuit in Block-A detects the train and places 180 Code on Block-A. The train detects the 180 Code and the onboard ATS is “armed”. Timer-A starts counting down from the pre-set value.
- A3. If the train does not enter Block-B before Timer-A expired (timer=0), the “No Code” in Block-B is changed to 180 Code. This will allow a train running at, or slower than, the speed limit to continue moving from Block-A to Block-B without interruption.
- A4. However, if the train runs at a speed higher than the speed limit sign in approach to ATS-SIG-A, and Timer-A has not expired (timer >0 second) by the time the train enters Block-B, the train will receive a “No Code” and will be tripped to stop.



A5. The initial Timer-A setting is based on the length of Block-A, the expected train speed profile in Block-A, and the equipment reaction time. For example, the train runs at a constant speed of 25 mph in Block-A: Timer-A setting = run time (25 mph in Block-A) – equipment reaction time.

To avoid incorrectly tripping a train that runs at the speed limit (with a tolerance of 2 mph above the speed limit), the timer may be set at a lower setting to allow for smooth train operation. The final setting of the timer value will be determined during the final design and be adjusted during the train runs testing.

B2. When a train enters Block-B, the track circuit in Block-B detects the train and Timer-B starts counting down from the pre-set value.

B3. If the train does not enter Block-C by the time Timer-B expired (timer=0), the “No Code” in Block-C is changed to 75 Code. This will allow a train running at, or slower than, the speed limit to continue moving from Block-B to Block-C without interruption. The 75 Code will turn off the onboard ATS function after train enters Block-C.

B4. However, if the train runs at a speed higher than the speed limit sign as it approaches ATS-SIG-B, and Timer-B has not expired (timer >0 second) by the time the train enters Block-C, the train will receive a “No Code” and will be tripped to stop.

B5. The initial Timer-B setting is based on the length of Block-B, the expected train speed profile in Block-B, and the equipment reaction time. For example, the train runs at 25 mph when it enters Block-B, then brakes to 10 mph before arriving at the end of Block-B: Timer-B setting = run time (25 mph in Block-B) + run time (25 mph to 10 mph in Block-B) – equipment reaction time

To avoid incorrectly tripping a train that runs at the speed limit (with a tolerance of 2 mph above the speed limit), the timer may be set at a lower setting to allow a smooth train operation. The final setting of the timer value will be determined during the final design and be adjusted during the train runs testing.

B6. If a train is tripped by the first ATS trip (ATS-SIG-A), depending on the train speed the train may be stopped inside Block-B or Block-C. After the train is stopped, the train operator will be required to contact the dispatcher and reset the train before resuming the train movement, and the process could take a few minutes. In all the cases, Timer-B will be expired and the second ATS trip (ATS-SIG-B) will no longer provide overspeed tripping function.

3.3.3 ATS-Signal

Figure 3-2 illustrates a pole mounted ATS Signal and countdown timer display that will be installed at each ATS tripping point. The ATS signal will consist of two heads: a horizontal bar lunar light and a vertical bar lunar light. A single digit light emitting diode (LED) countdown timer display will be installed under the ATS signal.



Figure 3-2. Typical ATS Signal, Count-Down Timer Display, and Speed Limit Sign



3.3.3.1 ATS Signal Head and Countdown Timer Display Function Descriptions

The following information describes the signal head and countdown timer display:

1. Initially all ATS signal heads and countdown timer display are dark if there is no train in approach block.
2. When a train enters approach block, the ATS signal horizontal bar light will lit. The countdown timer display will display flashing “—” if the timer is greater than 9 seconds. If the timer is equal to or less than 9 seconds it will display the countdown time until it reaches “0”.
3. When the timer expires (timer = 0), the ATS signal horizontal bar light and countdown timer display will be turned off, and the ATS signal vertical bar light will be turned on.
4. When the train passes the ATS signal, the ATS signal light and count-down timer display will be turned off.

3.3.4 Mandatory Stop Distance and ATS Stop Distance

3.3.4.1 Mandatory Stop Distance:

If a LRV train is tripped at ATS tripping point, the onboard ATS device will initiate a mandatory brake to stop the train. The formula used in calculating the mandatory stop distance for a normal train on a tangent dry track is as below:

$$\text{Mandatory Stop Distance (feet)} = 1.467 * V * T + (0.7333 * (V^2)) / (0.22 * G - A)$$

where

V = Entry speed, mph

T = Delay time = 3 seconds

A = Brake rate = -4.31 miles per hour per second (mphps), equivalent to -1.929 meters/second/second

G = Track grade, percent (%) grade, (if desirable, G can be set to zero for uphill track)



3.3.4.2 ATS Stop Distance

The ATS stop distance is the minimum distance required between the ATS tripping point and the protecting (stop) point. To consider factors that are not included in the mandatory stop distance calculations, a safety margin is added on top of the mandatory stop distance and the total distance is used as the ATS stop distance.

$$\text{ATS Stop Distance} = \text{Mandatory Stop Distance} * (100\% + \text{safety margin } \%)$$

The value of the safety margin is selected to meet the need of different applications. For this project, the safety margin of 10 percent will be used. The protecting (stop) point is the north point of the 10-mph curve. The location of ATS-A is set to trip a 45-mph overspeed train, and the location of ATS-B is set to trip a 25-mph overspeed train.

Table 3-3 shows the mandatory stop distance and ATS stop distance for this project.

Table 3-3. Mandatory Stop Distance and ATS Stop Distance

Entry Speed (mph)	Mandatory Stop Distance (feet)	ATS Stop Distance (feet)
45	543	597
25	216	238
Parameters		
	3	Second, reaction time
	-4.31	mphps, brake rate
	0	%, track grade, set to 0 for uphill track
	10	%, safety margin

3.3.5 Limitations of the Timer-Based ATS layout

As indicated in Section 3.1, the onboard ATS/cab signal equipment is not connected to the train speedometer and does not monitor the actual train speed. The proposed ATS layout uses a timer with a pre-set value and the fix block distance to determine if a train is over speed. As such, the timer circuit and ATS circuits may not be able to detect or trip all overspeed trains, especially if a train runs in a non-predictable or abnormal manner. For example, if a train enters the approach block in low speed or stops in the middle of the block and then accelerates to an overspeed, it is possible that by the time the train arrives at the tripping point the timer will have expired and ATS will not trip the train.



4 ATS Layout Design North of Exposition/Sable (proposed)

The conceptual ATS layout design for this project is based on the three-block/two-ATS-trip concept discussed in Section 3.3.2.

4.1 The ATS Layout Design

Table 4-1 and the following key notes describe the simplified conceptual ATS layout design (see Exhibit 1 for the full layout design).

Table 4-1. Simplified ATS Layout Design, North of Exposition/Sable

Key Note	Stationing	Descriptions
a	885+80	Metro Center Station South End, TSP-51, TSP-52
b	883+51	East Centerpoint Drive Bar-Signal, TSP-47, TSP-48, 25 mph SIGN
A	881+50	Begin of ATS, IJ/IB
		Block-A, TRK CKT 2030AT
B	877+50	ATS-SIG-A, IJ/IB, 25 mph SIGN, RELAY CASE-A
		Block-B, TRK CKT 2030BT
C	873+60	ATS-SIG-B, IJ/IB, 10 mph SIGN, RELAY CASE-B
		Block-C, TRK CKT 2030CT
D	871+67	End of ATS, IJ/IB
c	871+18	North Point of 10-mph Curve
d	870+90	Exposition/Sable, Bar-Signal, TSP-41, TSP-42, 10 mph SIGN

4.1.1 Descriptions and Key Notes

The following information describes the key notes shown in Table 4-1 (see Section 2.1 for description on key notes a and c).

- b. During the ATS testing and cutover, the TSP loops TSP-47 and TSP-48 will be restored by RTD or its contractor so that when a southbound train is detected by the loops, the information will be sent to the traffic signal controller at Exposition/Sable to provide transit priority function.
- A. Begin of ATS (north end of Block-A): The train accelerates from the Metro Center Station and reaches a speed of 25 mph, adding about 5 seconds from that point and using it as the north end of Block-A. Install a “Begin of ATS” sign.
- B. ATS-SIG-A (at boundary of Block-A and Block-B): In accordance with RTD’s evaluation, it is desirable to install the first ATS tripping layout to provide overspeed protection for trains approaching the 25-mph speed limit sign mounted on ATS-SIG-A. The ATS will trip an over speed train (up to 45 mph) to stop before it enters the 10-mph curve. Protection to train speed higher than 45 mph is not necessary for this application. The ATS tripping point A is set to approximately 632 feet from the north point of the 10-mph track curve, this distance exceeds the 597-foot minimum ATS stop distance requirement for a 45-mph train as mentioned in Section 3.3.4. Provide a relay Case-A for ATS-A control equipment at this location.

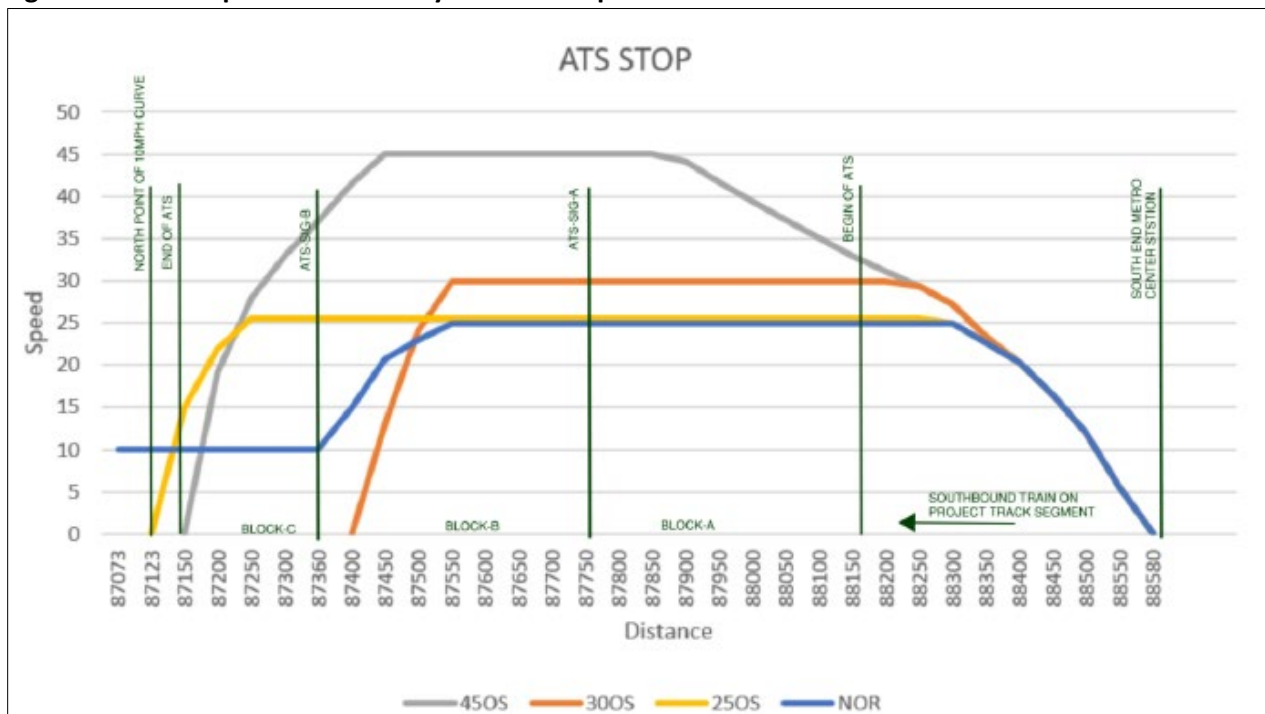


- C. ATS-SIG-B (at the boundary of Block-B and Block-C): with RTD’s evaluation, it is desirable to install the second ATS tripping layout to provide overspeed protection for trains approaching the 10-mph speed limit sign mounted on the ATS-SIG-B. The ATS will trip an over speed train (up to 25 mph) to stop before it enters the 10-mph curve. The ATS tripping point B is set to approximately 242 feet from the north point of the 10-mph track curve. This distance exceeds the 238-foot minimum ATS stop distance requirement for a 25-mph train as mentioned in Section 3.3.4. Provide a relay Case-B for ATS-B control equipment at this location. Relocate the 10-mph digital radar speed sign to the ATS-SIG-B location.
- D. End of ATS (south end of Block-C): The insulated joints will be located approximately 10 feet north of the embedded track at the Exposition/Sable intersection. Install an “End of ATS” sign at this location.

4.2 Train Speed Profile Analysis

Figure 4-1 illustrates the southbound train speed profiles on the Project Track Segment Track-A under different scenarios.

Figure 4-1. Train Speed Profile Analysis – ATS Stop



4.2.1 Train Speed Profile Descriptions

The following information describes each train speed profile:

- 45OS: The train accelerates from the Metro Center Station to 45 mph and continues that speed; when it arrives at ATS-SIG-A, the overspeed train is tripped to stop.
- 30OS: The train accelerates from the Metro Center Station to 30 mph and continues that speed; when it arrives at ATS-SIG-A, the overspeed train is tripped to stop.



- 25OS: The train accelerates from the Metro Center Station to 25 mph and continues that speed. The train passes through ATS-SIG-A without interruption; when it arrives at ATS-SIG-B, the train does not slow down to 10 mph and is tripped to stop.
- NOR: Normal train. The train accelerates from the Metro Center Station to 25 mph and continues that speed. The train passes through ATS-SIG-A without interruption and reduces its speed from 25 mph to 10 mph before it reaches ATS-SIG-B. The train pass through ATS-SIG-B without interruption.



5 ATS Layout Implementation North of Exposition/Sable (proposed)

5.1 Implementation Process Scope, Timeline, Supply Chain and Technical Issues

Upon CPUC approval, RTD will plan the implementation of the ATS layouts at the Exposition/Sable intersection location.

The implementation process will include the following:

- Development of contract documentation
- Contract award
- Contractor's final design and review
- Equipment assembly, installation, and testing
- System Integration Testing
- System certifications and commissioning

New wayside ATS layout installations will include the following:

- Relay cases, ATS/Cab signal code equipment, impedance bond, and insulated joint equipment will be the same or similar to equipment currently used in RTD's signal system. Timers will be railroad signal type vital timer or timer logic in vital signal processor.
- An ATS-signal, countdown timer display, and speed limit sign will be standard traffic signal equipment.
- All new wayside cables will be installed inside conduits. Existing spare conduit in express duck bank will be used where possible. New local conduits and pull boxes will be installed as needed.
- Electrical power from the utility power company will be used as the power source for the two new relay cases.

Change to the existing LRV onboard ATS/Cab Signal equipment is not needed.

5.2 Integration with Traffic Signal system

RTD will coordinate with the Aurora City Traffic Department during the design and implementation phases for inputs and recommendations.

After the new ATS layouts are installed and during the system integration testing, RTD or its contractor will restore the TSP-47 and TSP-48 loops at East Centrepoint Drive and test the TSP function for traffic/transit signals at the Exposition/Sable intersection. RTD will also coordinate with the Aurora City Traffic Department during the system integrating testing phase to include all traffic signal related testing. Testing such as TSP/traffic signal test for normal train operations and TSP/traffic signal test for abnormal train operations, including ATS overspeed train tripping and recovery, will be included.

5.3 Preliminary Hazard Analysis

The Preliminary Hazard Analysis Report is included in Exhibit 2 of this report.

5.4 Testing Protocol and Certifiable Items List

Testing protocol for this project will include but not be limited to the following:



1. **Factory Tests:** New control equipment will be assembled in new relay cases and tested in the contractor's facility prior to shipping to the field for installation.
2. **Field Installation Tests:** All new installations will be field tested in accordance with the approved circuit plan and installation plans.
3. **System Integration Tests:** A test train will be used to perform static and dynamic tests, such as the following:
 - Track circuit occupancy test
 - ATS/Cab signal code test
 - ATS signal light test
 - Countdown timer display test
 - Countdown timer setting field adjustment test
 - ATS normal train operation test
 - ATS overspeed train tripping function test
 - ATS overspeed train stopping distance test
 - TSP/Traffic signal integration test
 - Pre-commissioning test

RTD will use the standard system commissioning procedure including the Safe and Security Check List to verify that all required design, installation, testing, and documentation are satisfied prior to issuing the Certification of System Acceptance.

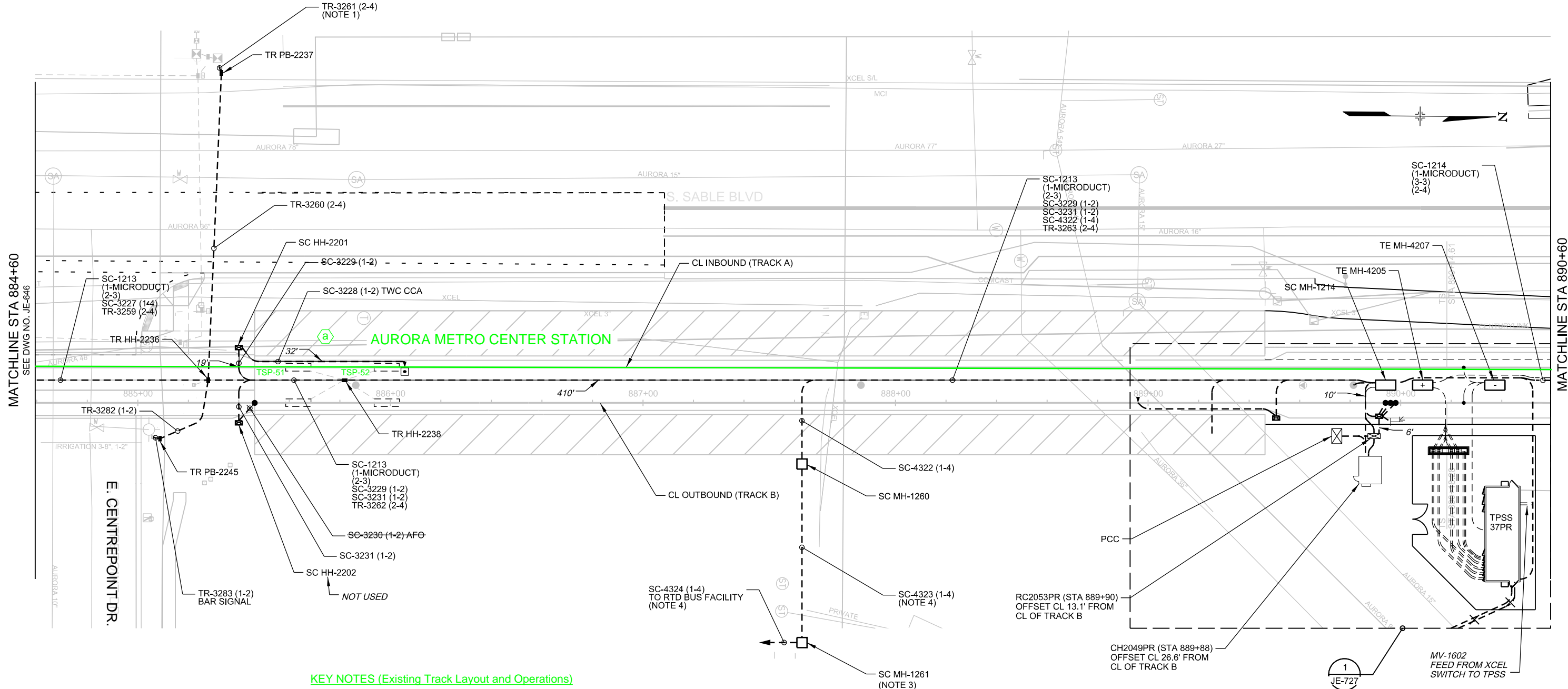
5.5 Rough Cost Estimations and Implementation Time Estimations

The rough time estimation for implementing the ATS layout is approximately 1 year.

The rough cost estimation for implementing the ATS layout is approximately \$876,000, (see Table 5-1).

Table 5-1. ATS Implementations Rough Cost Estimation

Categories	Estimated Cost
Preliminary Design, Contract Document Development	\$100,000
Relay Case - A: Circuit Design, Assembly, Testing	\$150,000
Relay Case - B: Circuit Design, Assembly, Testing	\$150,000
ATS Signal, Impedance Bond, IJ, Cabling, Conduits, Signage	\$150,000
System Integration and Testing	\$80,000
Engineering, Documentation, Indirect Cost, Construction Management	\$100,000
Subtotal:	\$730,000
Contingency:	20%
Total Estimated Cost:	\$876,000



MATCHLINE STA 884+60
SEE DWG NO. JE-646

MATCHLINE STA 890+60
SEE DWG NO. JE-648

KEY NOTES (Existing Track Layout and Operations)

(a) RTD Aurora Metro Center Station: Under normal operation, the southbound train uses the A-track to enter the station from the north; the mode of operation is street-run, and the speed limit is 35 mph. The service train is required to stop at the south end of the station to release and pick up passengers. The transit signal priority (TSP) detection loops (TSP-51 and TSP-52) on the south end of station are used to provide the stop bar recall function when the loops detect a southbound train, the TSP function of the East Centrepoint Drive traffic signal system will be initiated.

Color Code:
 Black/Grey: existing/background
 Green: notes and markups on existing installations associated to this project
 Purple: notes and markups on new installations associated to this project
 Blue: project sheet title & notes

EXHIBIT-1: sheet 1/4
 ATS Layout north of Exposition/Sable (Proposed)
 by HNTB, 06/16/23

NO.	REVISIONS	BY	DATE

DESIGNED BY:	DATE:	CHECKED BY:	DATE:
DRAWN BY:	DATE:	APPROVED BY:	DATE:

HORZ. SCALE: 1"=20'
 VERT. SCALE: N/A



HALF SIZE - Double The Scale

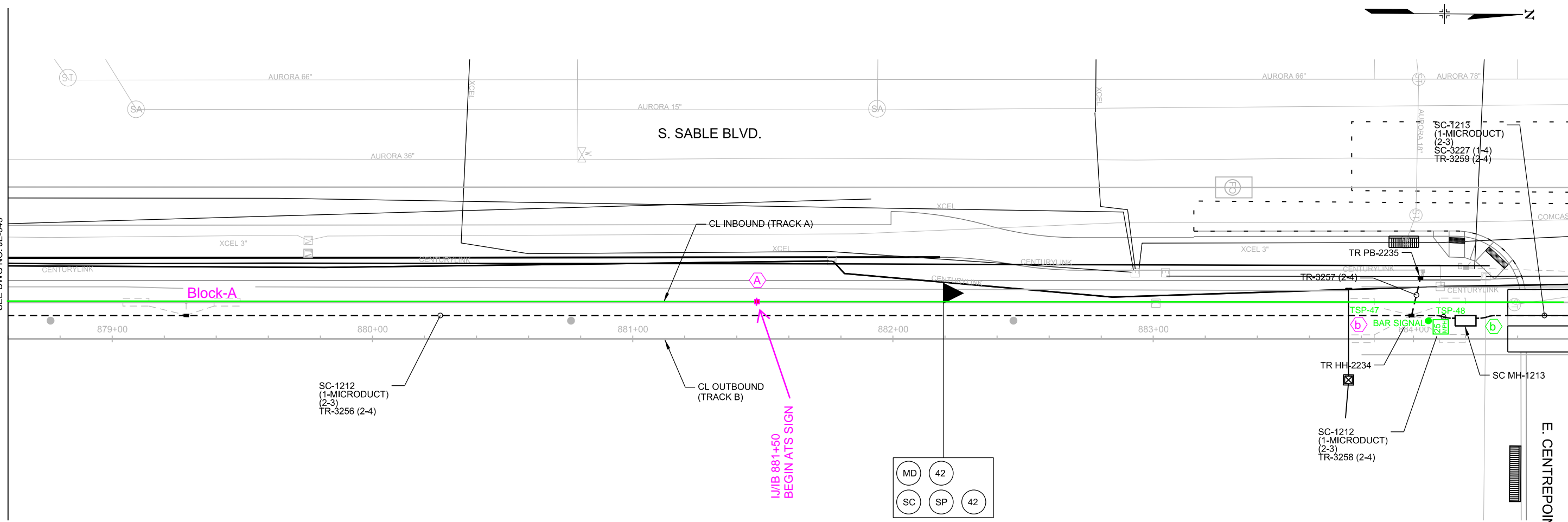


I-225 RAIL LINE
 REGIONAL TRANSPORTATION DISTRICT
 ATS IMPLEMENTATION PLAN
 NORTH OF SABLE/EXPOSITION
 DRAFT

SHEET REFERENCE NUMBER:
 JE-647

MATCHLINE STA 878+60
SEE DWG NO. JE-645

MATCHLINE STA 884+60
SEE DWG NO. JE-647



KEY NOTES (ATS Layout - Proposed)

- b During the ATS testing and cutover, the TSP loops TSP-47 and TSP-48 will be restored by RTD or its contractor that when a south bound train is detected by the loops, the information will be sent to the traffic signal controller at Exposition/Sable to provide transit priority function.
- A Begin of ATS (north end of Block-A): The train accelerates from the Metro Center Station and reaches a speed of 25 mph, adding about 5 seconds from that point and using it as the north end of Block-A. Install a "Begin of ATS" sign.

KEY NOTES (Existing Track Layout and Operations)

- b East Centrepoint Drive crossing: When the train is ready to depart the Metro Center Station, the train operator observes the traffic system controlled LRV transit signal (bar-signal) located on the south side of the road. The train operator accelerates the train when the LRV transit-signal displays a "go" aspect. The train operator follows the street-run operation rules and observes the 25-mph speed limit sign mounted on the LRV transit signal. Currently, the TSP detection loops TSP-47 and TSP-48 on the south side of East Centrepoint Drive are not used and the TSP function on the south bound train at the Exposition/Sable intersection traffic signal system is disabled.

Color Code:

- Black/Grey: existing/background
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EXHIBIT-1: sheet 2/4
ATS Layout north of Exposition/Sable (Proposed)
by HNTB, 06/16/23

NO.	REVISIONS	BY	DATE

DESIGNED BY:	DATE:	CHECKED BY:	DATE:
DRAWN BY:	DATE:	APPROVED BY:	DATE:

HORZ. SCALE: 1"=20'
VERT. SCALE: N/A

HALF SIZE - Double The Scale

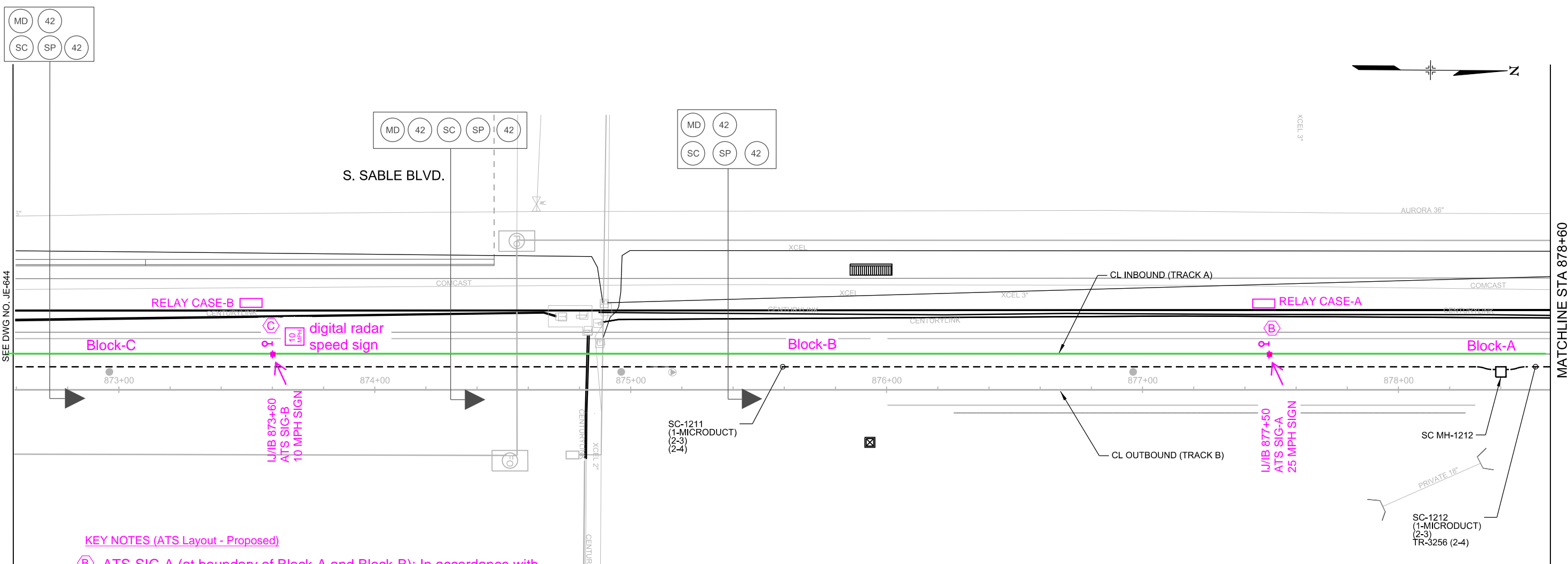


I-225 RAIL LINE
REGIONAL TRANSPORTATION DISTRICT
ATS IMPLEMENTATION PLAN
NORTH OF SABLE/EXPOSITION
DRAFT

SHEET REFERENCE NUMBER:
JE-646

MATCHLINE STA 872+60
SEE DWG NO. JE-644

MATCHLINE STA 878+60
SEE DWG NO. JE-646



KEY NOTES (ATS Layout - Proposed)

- ⓑ ATS-SIG-A (at boundary of Block-A and Block-B): In accordance with RTD's evaluation, it is desirable to install the first ATS tripping layout to provide overspeed protection for trains approaching the 25-mph speed limit sign mounted on ATS-SIG-A. The ATS will trip an over speed train (up to 45 mph) to stop before it enters the 10-mph curve. Protection to train speed higher than 45 mph is not necessary for this application. The ATS tripping point A is set to approximately 632 feet from the north point of the 10-mph track curve, this distance exceeds the 597-foot minimum ATS stop distance requirement for a 45-mph train as mentioned in Section 3.3.4. Provide a relay Case-A for ATS-A control equipment at this location.
- ⓒ ATS-SIG-B (at the boundary of Block-B and Block-C): with RTD's evaluation, it is desirable to install the second ATS tripping layout to provide overspeed protection for trains approaching the 10-mph speed limit sign mounted on the ATS-SIG-B. The ATS will trip an over speed train (up to 25 mph) to stop before it enters the 10-mph curve. The ATS tripping point B is set to approximately 242 feet from the north point of the 10-mph track curve. This distance exceeds the 238-foot minimum ATS stop distance requirement for a 25-mph train as mentioned in Section 3.3.4. Provide a relay Case-B for ATS-B control equipment at this location. Relocate the 10-mph digital radar speed sign to the ATS-SIG-B location.

Color Code:
 Black/Grey: existing/background
 Green: notes and markups on existing installations associated to this project
 Purple: notes and markups on new installations associated to this project
 Blue: project sheet title & notes

EXHIBIT-1: sheet 3/4
 ATS Layout north of Exposition/Sable (Proposed)
 by HNTB, 06/16/23

NO.	REVISIONS	BY	DATE

DESIGNED BY:	DATE:	CHECKED BY:	DATE:
DRAWN BY:	DATE:	APPROVED BY:	DATE:

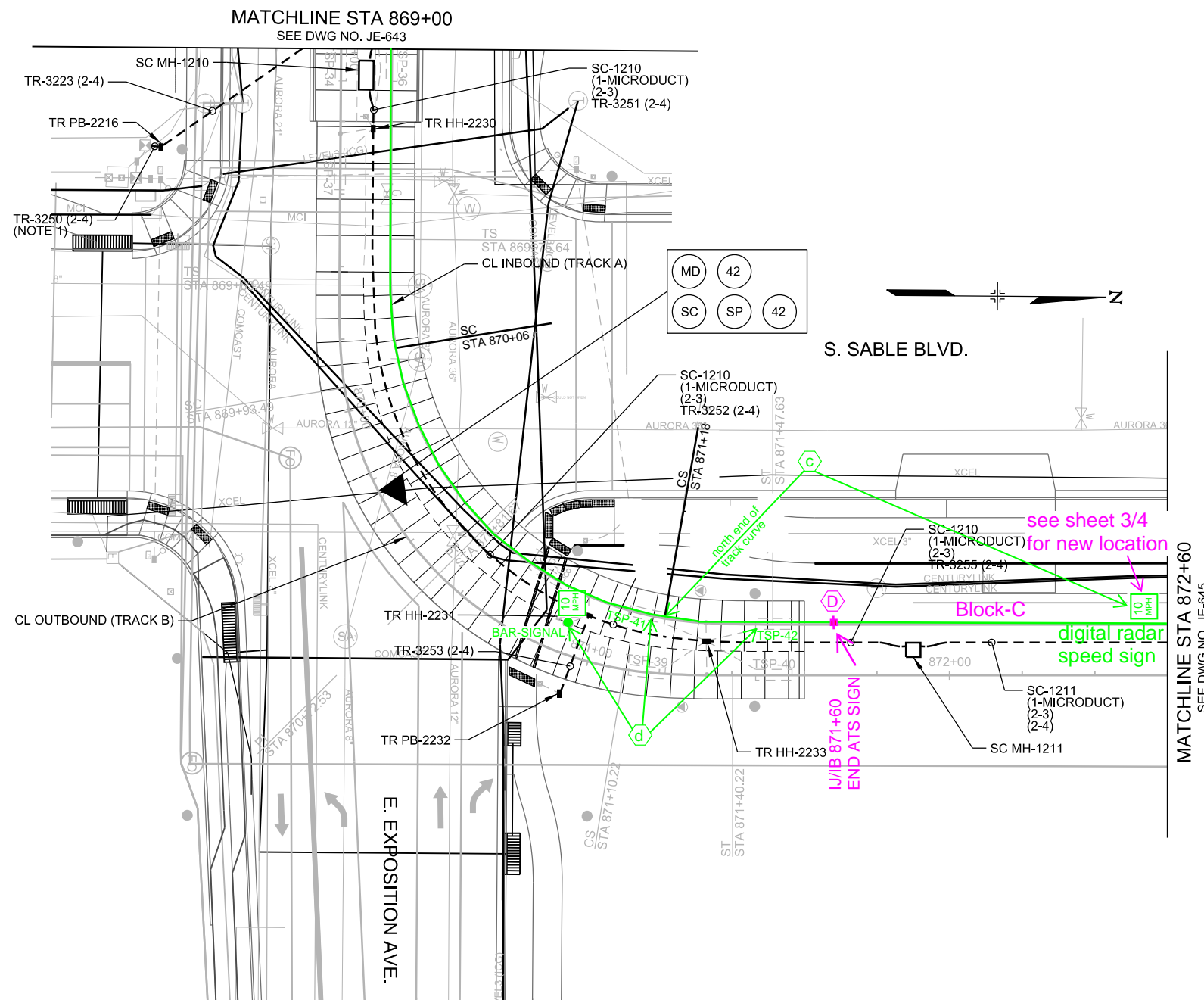
HORZ. SCALE: 1"=20'
 VERT. SCALE: N/A

HALF SIZE - Double The Scale



I-225 RAIL LINE
 REGIONAL TRANSPORTATION DISTRICT
 ATS IMPLEMENTATION PLAN
 NORTH OF SABLE/EXPOSITION
 DRAFT

SHEET REFERENCE NUMBER:
 JE-645



KEY NOTES (Existing Track Layout and Operation)

- Ⓒ Curve track at the Exposition/Sable intersection: This curve track is a compound curve and has a 10-mph design train speed limit. The 10-mph speed limit starts on the north end curve-to-spiral (CS) point at 871+18 and ends on the west end spiral-to-curve (SC) point at 870+06. The train operator observes the 10-mph speed limit sign (digital radar speed sign) that is placed in advance to the north of the curve point and the 10-mph signal mounted at the LRV transit signal and brakes the train to 10 mph prior to entering the curve.
- Ⓓ Exposition/Sable intersection LRV transit signal: A traffic system controlled LRV transit signal (bar-signal) is used to control the train movement through the intersection. If the signal displays a "stop" aspect, the train operator stops the train before the LRV transit signal. The TSP loops TSP-41 and TSP-42 at the location are used for the stop bar recall function. If the LRV transit signal displays a "go" aspect, the operator is allowed to operate the train at 10 mph through the intersection.

KEY NOTES (ATS Layout - Proposed)

- Ⓓ End of ATS (south end of Block-C): The insulated joints will be located approximately 10 feet north of the embedded track at the Exposition/Sable intersection. Install an "End of ATS" sign at this location.

Color Code:

- Black/Grey: existing/background
- Green: notes and markups on existing installations associated to this project
- Purple: notes and markups on new installations associated to this project
- Blue: project sheet title & notes

EXHIBIT-1: sheet 4/4
 ATS Layout north of Sable/Exposition (Proposed)
 by HNTB, 06/16/23

NO.	REVISIONS	BY	DATE

DESIGNED BY:	DATE:	CHECKED BY:	DATE:
DRAWN BY:	DATE:	APPROVED BY:	DATE:

HORZ. SCALE: 1"=20'
 VERT. SCALE: N/A

HALF SIZE - Double The Scale



I-225 RAIL LINE
 REGIONAL TRANSPORTATION DISTRICT
 ATS IMPLEMENTATION PLAN
 NORTH OF SABLE/EXPOSITION
 DRAFT

SHEET REFERENCE NUMBER:
 JE-644

RTD R-Line ATS Plan, Final Report, 6-16-2023
Exhibition - 2: Preliminary Hazard Analysis Report

Location: North of East Exposition Ave/South Sable Blvd Intersection
Project Description: ATS implementation to trip over speed train

Reviewed with RTD Team (Yes/No) and Identified Work to Complete (Highlighted in grey in excel sheet)	1. Identify Risk			2. Evaluate Risk			3. Assess Risk					4. Implement Controls				Supplemental Information
	Item No.	Hazard Identified	Impact of Uncontrolled Identified Hazard	Control or Mitigation Identified to Reduce the Risk	Type of Control (Hierarchy of Controls)	Category of Control/Mitigation	Severity Categories	Probability Levels	Risk Assessment	Anticipated Risk after Control or Mitigation has been Implemented	Additional Considerations to Support Why the Control(s) was/were Selected	Responsible for Implementing Control/Mitigation	Should be Consulted when Implementing Control/Mitigation	Responsible for Maintaining Implemented Control(s)/ Mitigation(s)	Date of Control(s)/ Mitigation(s) Implemented	
Yes	1	Inadequate and additional operator training	Fatalities, injuries, property damage, and service disruptions	Provide comprehensive training programs for train operators, focusing on safe operating speeds and the consequences of speeding. Conduct regular refresher courses. Additional driver training for Automatic Train Stop (ATS).	Administrative Controls – training	Administrative	1	D	Medium	Medium	Proper training and refresher courses can help ensure train operators understand and adhere to safe operating speeds.	RTD Light Rail Operations	RTD Light Rail Operations	RTD Light Rail Operations	TBD	n/a
Yes	2	Inadequate motor vehicle driver education	Fatalities, injuries, property damage, and service disruptions	Implement new public awareness campaigns to educate motorists about light rail intersections, traffic rules, and the importance of vigilance.	Administrative Controls – training	Administrative	n/a	n/a	n/a	n/a	Discussed and recognized not to assess risk, the project is not changing the intersection operations.	n/a	n/a	n/a	TBD	n/a
Yes	3	Excessive Speed beyond intended design	Fatalities, injuries, property damage, and service disruptions	Implement overspeed protection; with Automatic Train Stop (ATS).	Engineering Controls – isolate people from the risk	Engineering	1	D	Medium	Medium	ATS can reduce the risk of derailling on curve track caused by operator speeding. Trip point and speed, stops the train. Two trip points.	RTD Light Rail Operations, RTD Capital Programs	City of Aurora (COA) Traffic Engineering, RTD Maintenance of Way	RTD Maintenance of Way	TBD	n/a
Yes	4	ATS can not provide full overspeed protection under all operation scenarios	Fatalities, injuries, property damage, and service disruptions	Implement ATS trips based on calculated timing.	Engineering Controls – isolate people from the risk	Engineering	1	D	Medium	Medium	The calculated ATS trips are based on operations conforming to design intent as an interim mitigation until a systemwide solution is planned and implemented for Speed Control.	RTD Light Rail Operations, RTD Maintenance of Way, RTD Capital Programs (Engineering)	RTD Light Rail Operations, RTD Maintenance of Way, RTD Capital Programs (Engineering), City of Aurora (COA) Traffic Engineering	RTD Light Rail Operations	TBD	n/a
Yes	5	ATS tripping mandatory brake	Possible injury to passengers when mandatory brake is applied to the train	Implementation of a timer based system with a wayside countdown display to reduce the likelihood of trips, and supervisor oversight of LRT Operations.	Engineering Controls – isolate people from the risk, Administrative Controls – training	Engineering, Administrative	5	C	Low	Low	System has 730 runs a day	RTD Light Rail Operations, RTD Capital Programs	RTD Light Rail Operations, RTD Maintenance of Way, RTD Capital Programs (Engineering), City of Aurora (COA) Traffic Engineering	RTD Light Rail Operations	TBD	n/a