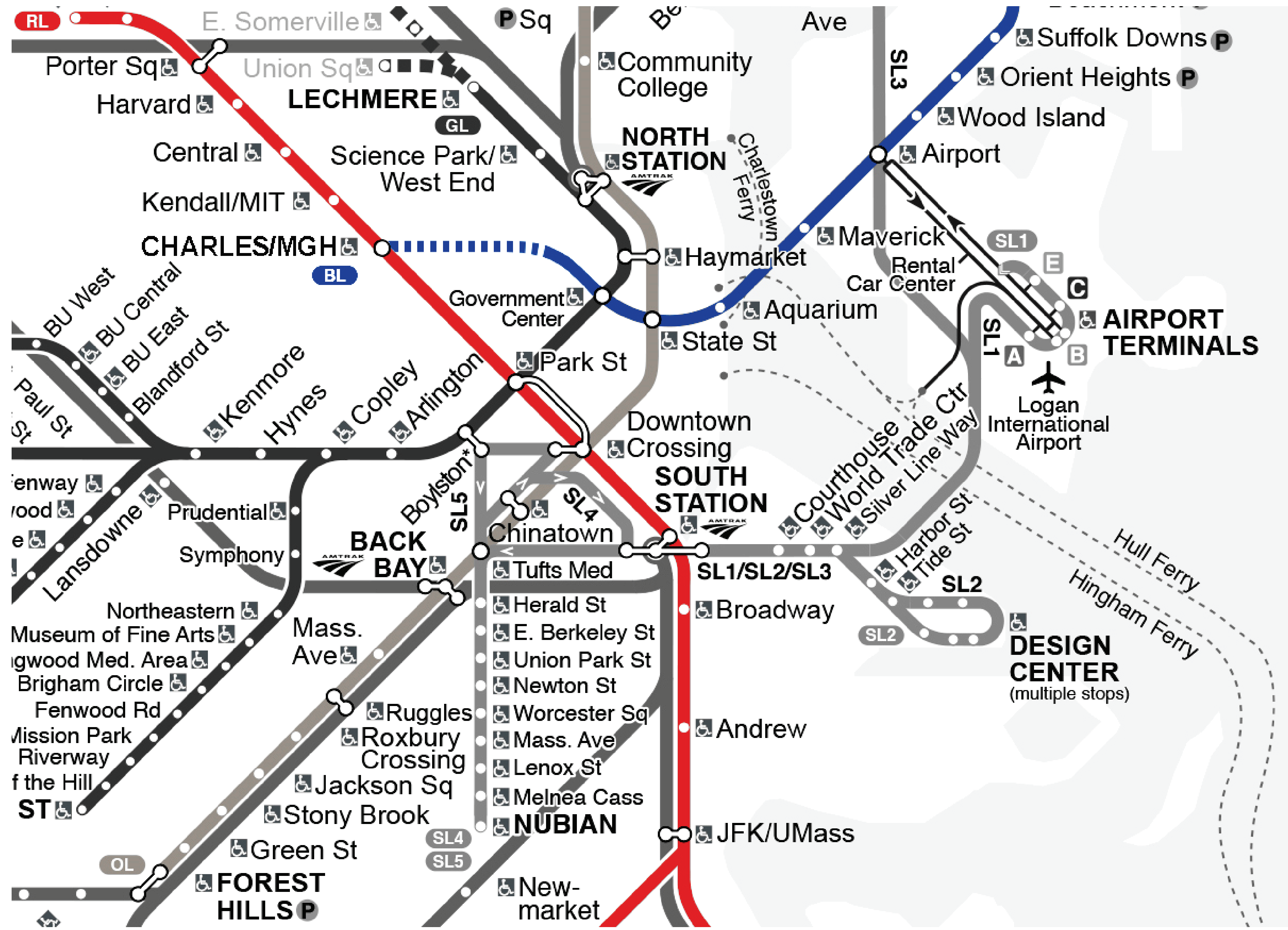
Red Blue Connector Concept Design Report

FINAL November 15, 2021

Appendix A

Relevant information from previous technical studies



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Appendix A

Engineering Concepts for DEIR (2010)

Sections Referenced in Red Blue Connector Concept Design Report (November 15, 2021)

Red Line/ Blue Line Connector Project

VOLUME I

10% CONCEPTUAL ENGINEERING REPORT

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Submitted: **August 2010**

Referenced Sections Highlighted in Yellow

VOLUME I, 10% CONCEPTUAL DESIGN REPORT

VOLUME II- APPENDICES

VOLUME III-DRAWINGS

Alternative 1 Drawings

Alternative 2 Drawings

The remainder of the tunnel construction traveling west will be a mined tunnel construction which will be situated below Cambridge Street minimum of 30 ft. from the roadway surface to the top of the proposed tunnel.

6.1.3.3 Track Work

The proposed track segment between Government Center Station and Charles/ MGH Station will use continuous welded rail with direct fixation to the floor slab of the proposed concrete tunnel.

The running rail will be carbon steel 115 RE Section conforming to current AREMA specifications for steel rails. Resilient rail fasteners will provide electrical isolation and restrain the rail from movement. A 132RE section restraining rail will be installed on all curves.

6.1.3.4 Track Modifications between State Street and Government Center Stations

In order to allow for the train service to temporarily terminate at the Government Station during construction, modifications to the track segment between the State Street Station and the Government Center Station will be required.

The existing track segment has a right-hand crossover just east of the Government Center Station. The proposed project will install a left-hand crossover situated halfway between the two stations which will allow for the flexibility of train movements and reduce the headway at the Government Center Station which will temporarily be the end of the Blue Line.

The existing vertical curve along the profile of the tracks must be modified for a length of 140 ft. to reduce the curve length by 40 ft. to allow the proposed No. 8 turnouts to be installed on tangent track. The track work construction for this segment will consist of timber ties on ballast similar to the existing conditions.

Signals

This report provides:

- The existing signal design criteria for the Blue Line.
- The expected run time and headway capability of the Blue Line signal system after the completion of the Blue Line Signal Upgrade Project.
- The conditions in the Bowdoin Loop and the interface area to the construction project.
- A preliminary estimate of the impact on headways and run times of the extension of the Blue Line to Charles/ MGH Station.
- The issues involved in turning trains back at Government Center during construction and the proposed second crossover for the Government Center Interlocking.
- Current MBTA standards for signals, track circuits, interlocking control, communications with the Operations Control Center and communications with other locations on the Blue Line.
- Some proposed changes for track circuits and signals.
- General requirements for interlocking design at the new Blue Line MGH station in light of MBTA Blue Line design principles and Blue Line capacity requirements.
- General requirements for signal bungalow location, size, HVAC, communications and networking, power, and equipment racks.

6.1.4 Blue Line Signal Block Design Criteria

The existing Blue Line Signal System is an absolute block system with trip stop enforcement.

Signal control lines are designed to provide a 35% buffer on top of the de-rated safe braking distance.

Safe braking distances are calculated upon the following scenario:

- The train clears the last timed signal at the average speed allowed by that signal without getting tripped. The average speed is calculated according to the equation:

$$Average\_speed = \frac{Track\_circuit\_length\_Distance\_from\_signal\_to\_insulated\_joint}{Timer\_setting\_+3\_seconds}$$

- The train then accelerates at 110% of the AW0 maximum acceleration curve[4], less the effects of Davis resistance, until it is tripped for violating the protected signal.
- The train continues to accelerate for another 600 milliseconds, coasts for 100 milliseconds and builds up brakes for 400 more milliseconds.
- The train brakes to a stop at the worst tested emergency brake rate de-rated by 25%.
- The 35% buffer is for adhesion issues. Due to the presence of greasers on curves, MBTA does not permit exceptions to this rule in tunnels.

In addition to enforcing train separation, the Blue Line Signal system also enforces civil speed restrictions on curves and through crossovers.

For civil speed restrictions timed signals are used that permit an average speed through the track circuit in front of the signal equal to the required civil speed. Timed signals are signals that clear only after the train has been in the approaching track circuit for a specified amount of time. Civil speeds are enforced while any part of the train is on the speed restricted curve.

The conservative signal design criteria used by the MBTA requires close spacing of timed signals in the downtown area where stations are extremely close together and where significant grades exist between stations. All signals from State to Bowdoin and back are timed signals.

For the Red Line/ Blue Line Connector, MBTA signal block design criteria dictate that:

- Timed signals will need to be installed from Government Center through 300 feet beyond the second curve in the connector. Speeds will be limited to 20 mph.
- Timed signals will be needed to enforce a 15 mph speed limit through the Number 8 crossover at the MGH interlocking.
- Timed signals will be needed to enforce a 10 mph speed limit in the station tracks at MGH.
- No trains will be allowed to be stored in the MGH storage tracks during revenue service for safe braking reasons.
- Conditionally timed signals will be needed to slow trains down on the approach to the MGH interlocking when the interlocking signal is at stop or the switches are aligned for a reverse move.
- Controlling speeds down the slope approaching the MGH interlocking will require closely spaced timed signals.
- A timed signal will be required 300 feet east of the MGH interlocking to limit train speeds to 15 mph until the rear of the train clears a reverse switch coming out of MGH.

6.1.5 Existing Run Times and Headways

The MBTA Blue Line Signal Upgrade Project has been completed. When the installation of the catenary for the new crossover at Wonderland is complete, the improvements to headway and run times will be complete. The upgraded signal system will provide a two track turn back at Wonderland and will increase speeds on the eastbound approach to Orient Heights station from 20 mph to 40 mph. For this report we will use the estimated run times for the new system rather than the data for the existing signal system.

The following tables indicate the best runtimes and headways for the Blue Line after the Signal update project is completed. The tables assume 6-car trains.[5]

4 See Appendix 1 for the acceleration curve and the braking rates.

Table 6-1 Estimated Minimum Blue Line Run Times after Signal Upgrade

	Best times from run time survey before Signal Mods (no dwell time)	#5 car with all Signal Mods (no dwell time)		Dwell Time AM	Dwell Time PM	Dwell Time off Peak	No 5 AM with modified Signals	No.5 PM with Modified Signals	No 5 off peak with modified signals
Eastbound									
Gov to State	00:48.0	00:51.0	Gov	00:25.0	01:05.0	00:38.0	01:16.0	01:56.0	01:29.0
State to Aquarium	00:59.0	00:48.6	State	00:25.0	01:00.0	00:33.0	01:13.6	01:48.6	01:21.6
Aquarium to Mav	02:17.0	02:01.1	Aquarium	00:17.0	00:35.0	00:20.0	02:18.1	02:36.1	02:21.1
Mav to Airport	01:47.0	01:30.0	Maverick	00:20.0	00:36.0	00:24.0	01:50.0	02:06.0	01:54.0
Airport to Wood	01:31.0	01:13.5	Airport	00:40.0	00:25.0	00:30.0	01:53.5	01:38.5	01:43.5
Wood to OH	02:31.0	02:03.2	Wood Island	00:14.0	00:23.0	00:15.0	02:17.2	02:26.2	02:18.2
OH to Suffolk	01:03.0	01:06.6	Orient Hts.	00:14.0	00:31.0	00:20.0	01:20.6	01:37.6	01:26.6
Suffolk to Beach	01:05.0	01:08.3	Suffolk	00:14.0	00:23.0	00:15.0	01:22.3	01:31.3	01:23.3
Beach to Revere	01:29.0	01:31.0	Beachmont	00:15.0	00:27.7	00:15.0	01:46.0	01:58.7	01:46.0
Revere to Wonderland	01:22.0	01:10.6	Revere	00:15.0	00:27.0	00:15.0	01:25.6	01:37.6	01:25.6
Total outbound Gov to Wonderland	14:52.0	13:23.1					16:43.1	19:16.8	17:09.1
			Wonderland	0:00:40	00:40.0	0:00:28			
Turn back time free running	03:24.0	04:00.0	Wonderland Turn back +EB dwell.				04:40.0	04:40.0	04:28.0
Westbound									
Wonderland to Revere	00:54.0	00:58.7	Wonderland	00:40.0	00:30.0	00:28.0	01:38.7	01:28.7	01:26.7
Revere to Beachmont	01:25.0	01:29.8	Revere	00:17.0	00:15.0	00:17.0	01:46.8	01:44.8	01:46.8
Beachmont to Suffolk	01:02.0	01:08.5	Beachmont	00:16.0	00:18.0	00:19.0	01:24.5	01:26.5	01:27.5
Suffolk to O.H.	01:00.0	01:01.7	Suffolk	00:15.0	00:15.0	00:19.0	01:16.7	01:16.7	01:20.7
O.H. to Wood Island	02:20.0	02:00.2	Orient Hts.	00:30.0	00:20.0	00:20.0	02:30.2	02:20.2	02:20.2
Wood Island to Airport	01:26.0	01:12.1	Wood Island	00:20.0	00:25.0	00:15.0	01:32.1	01:37.1	01:27.1
Airport to Maverick	01:34.0	01:44.9	Airport	00:40.0	00:32.0	00:31.0	02:24.9	02:16.9	02:15.9
Maverick to Aquarium	01:57.0	01:48.1	Maverick	00:45.0	00:32.0	00:40.0	02:33.1	02:20.1	02:28.1
Aquarium to State	00:56.0	00:53.7	Aquarium	00:24.0	00:22.0	00:34.3	01:17.7	01:15.7	01:28.0
State to Government	00:48.0	00:52.0	State	00:35.0	00:30.0	00:38.0	01:27.0	01:22.0	01:30.0
Total Inbound	13:22.0	13:09.8					0:17:52	0:17:09	0:17:31
			Government	00:40.0	00:25.0	00:33.0			
Government inbound to Government outbound around Bowdoin Loop	04:04.0	03:49.0	GVT west to GVT east + GVT west dwell	04:29.0	04:14.0	04:22.			
Total Free running Run Time Round Trip	35:42.0	34:22.9	Total Round Trip time with no trains running up against each other				43:43.9	45:19.5	43:30.1

5 Headways and Run times are from MBTA Signal Division design documents for the Blue Line Signal upgrade project. Dwell times are based on a run time and dwell time survey conducted in March of 2004. Dwell times may be less with 6-car trains.

Given the above run times, the size of the Blue Line fleet, and assuming 90% fleet availability, the shortest possible scheduled headway would be 3 minutes and 15 seconds. However, we would normally add 15% or 20% to the run times to account for the fact that most operators will not operate so close to the signal system capability and for variations in dwell time. As a result, the shortest real scheduled head way would be between 3 minutes and 44 seconds and 3 minutes and 53 seconds.

Table 5-2 Minimum Headway Inside the Tunnel

	Dwell (seconds)	6-No 5 car with Signal Mods (seconds)
Eastbound AM		
Bowdoin East	15	109
Government East	25	105.31
State East	25	107.8
Aquarium East	17	88.7
Maverick East	20	73.5
Westbound AM		
9012	0	104
9006	0	86.4
Maverick West	45	124.5
Aquarium West	24	98.3
State West	35	114.5
Government West	40	136.4
902 (Bowdoin)	0	125.5-130

	Dwell (seconds)	6-No 5 car with Signal Mods (seconds)
Eastbound PM		
Bowdoin East	21	115
Government East	63	138
State East	60	128.8
Aquarium East	36	107.7
Maverick East	36	89.5
Westbound PM		
9012	0	104
9006	0	73.4
Maverick West	32	117.5
Aquarium West	22	96.3
State West	30	109.5
Government West	25	126.4
902 (Bowdoin)	0	125.5-130

As can be seen from Table 2 above, Government Center is the headway pinch point for the west end of the Blue Line. The Wonderland turn back is the pinch point for the east end of the Blue Line where minimum headway varies from 1 minute 46 seconds to 2 minutes 23 seconds, assuming two minutes for the operator to change ends. The Red Line/ Blue Line Connector Project should not increase minimum headways at the new MGH location beyond the headways at Wonderland.

6.1.6 Bowdoin Loop

Presently the Bowdoin Loop is the turn back for the west end of the Blue Line. The extremely tight curves in the Bowdoin loop necessitate a 5 mph speed limit through the loop. Signal 902 at the end of the westbound platform is timed for 40 seconds to slow down trains approaching the loop. Trains are restricted to 5 mph until they reach the middle of the eastbound platform at signal 901. Speed is then limited to 10 mph until just past the end of the Bowdoin Eastbound platform. Speed is restricted to 18 mph the rest of the way back to Government Center. The best calculated time for trains to go from Government Center East to Government Center West is 3 minutes and 49 seconds, including 21 seconds for loading and unloading passengers at each side of the Bowdoin platform.

The Red Line/ Blue Line Connector Project will eliminate the Bowdoin Loop and the existing station. This will require new signals in the area from Bowdoin to Government Center in both directions.

Even the signals that are not in the area of construction will be affected. The existing signals are controlled from cases that are old and have little room to allow modifications. All existing signals between Bowdoin and Government Center should be replaced and controlled from a new Government Center Signal bungalow.

The positive results of eliminating Bowdoin Loop include elimination of the long time it takes trains to go around it as well as a considerable reduction in wheel and track wear. The time savings from eliminating Bowdoin Loop will considerably mitigate the run-time impact of extending the Blue Line.

6.1.7 Headway and Run Time impact of the Red Line/ Blue Line Connector

Full assessment of the impact of the various options for the Red Line/ Blue Line Connector on headway and runtime will require development of a signal block layout. Block design is an iterative process of laying out signals, doing a safe braking analysis and run time analysis and refining the design to get an optimum signal design. Such a task is beyond the scope of this phase of the project. However the following points can be made:

- MGH will be the bottleneck of the extension.
- Tunnel designs that allow more level track in front of the diamond crossover between existing Charles/ MGH and existing Bowdoin Stations will facilitate reduction of turn back time and headway at MGH.
- In Alternative 2, including a new Bowdoin Station on the Red Line/ Blue Line Connector will add at least one minute to run times due to dwell time and starting and stopping time.
- The use of conditional timers on the approach to MGH interlocking and to Bowdoin and Government Center Stations will be necessary to allow safe braking down the hill on the approach to the interlocking and to allow the best recovery times.
- 10 mph timed signals will be required in the platform track circuits at MGH to allow safe braking before the end of the tunnel.

Based on allowable civil speeds, the speed restrictions required to slow trains down on the approach to a terminal location and 4 minutes to change ends at MGH, the extension should add:

- 3.8 to 4 minutes to trip times if Bowdoin Station is not replaced.
- 4.8 to 5 minutes if Bowdoin Station is replaced.

Trip time estimates with and without the connector include dwell time but do not account for the kind of congestion that develops after delays. Also not included is the impact of MGH station on dwell time at Government Center.

It should also be possible to keep headways at the MGH turn back close to the Wonderland levels. The initial ball park estimate is that the Red Line/ Blue Line Connector would mean a 7 % reduction in maximum line capacity for the No Bowdoin Alternative and a 9 % reduction for the Bowdoin Alternative. The signal system should support roughly the same headway as without the extension.

6.1.8 Government Center Crossover During Construction

Government Center Station is the bottle neck on the Blue Line for both the morning and afternoon rush hours with headways on the West side in the morning of 2 minutes and 16 seconds and headways on the East side in the afternoon of 2 minutes and 18 seconds. If trains are delayed in the afternoon headways get much worse due to dangerous levels of platform crowding.

At the east end of Government Center Station is the Number 4 Interlocking. This interlocking has a single crossover from the westbound platform to the eastbound track. Traffic is stopped at State Street Station while the crossover move is made. Use of this interlocking “as is” to turn back trains during construction is problematic.

- Trains would have to be brought into the Westbound Government platform slowly due to the need to provide safe braking in front of the construction site.
- Unless an operator fall back plan was used, the time required to change ends during rush hour crowding would be at least 2 minutes.
- A route could not be set up for the next train until the previous train was pulling into State Street Eastbound platform.
- Estimated minimum headway using the crossover for turn back without fall back =4 minutes.
- Estimated headway using the crossover for turn back with fall back = 3 minutes 30 seconds.

As a result of the terrible impact on headway of using the Government Center Interlocking “as is”, STV has proposed adding a second crossover to the Number 4 Interlocking. The second crossover would allow a minimum headway of 2 minutes. This would provide a vast improvement in recovery time.

6.1.9 Design Issues for Two Track Turn back at Government Center

Due to the location of the Signal bungalow as well as support columns and beams at Government Center, a diamond crossover is not an option. Therefore, a second crossover, 4-2, is proposed to convert the interlocking from single crossover to a universal crossover. See Figure 6-3 Government Center Interlocking with Changes.

The proposed location of a second crossover would require moving the 4-2W signal east from its current location at 1308+91 (signal stationing) to approximately 1306+80.

The MBTA's existing safe braking analysis shows that if a train were to overrun either 918 or 916 signal it may not stop before the new 4-2 switch. If we add just 1 second to the time for the 918 signal, it would, however, stop before interfering with the existing 4-1 crossover. In order to protect the new 4-2 crossover while allowing trains to move into State Street when 4-2W signal is cancelled, overlap locking between 922 Signal and 4-2 switch is required. (4-2W would be canceled during setup of any route and during of a move over 4-1 crossover out Government Center.)

- The overlap locking conditions would be:
  - 4-2 switch is normal.
  - A train enters 924 Track circuit leaving Aquarium.

- Overlap locking would allow 922 and 918 signals to clear even with 4-2W at stop.
- Overlap locking would keep 4-2 switch locked normal as the train progressed into State Street Station.
- The overlap locking would release after the train had been in State Street Station for a preset time that would guarantee the train speed is less than 10 mph.

Sectional release of the 4-1 Switch should be implemented when the train leaving track 1 or track 2 from Government Center clears the 4-1 track circuit. This will save approximately 6 seconds on turn back time.

A timed signal (909) opposite the 4-1E signal at Government Center will need to be added to control speed through new 4-2 crossover to 15 mph.

Adding the new crossover in the Number 4 interlocking would also require significant changes in the non-vital logic programs in the Government Center PLC's as well as the Operations Control Center software.

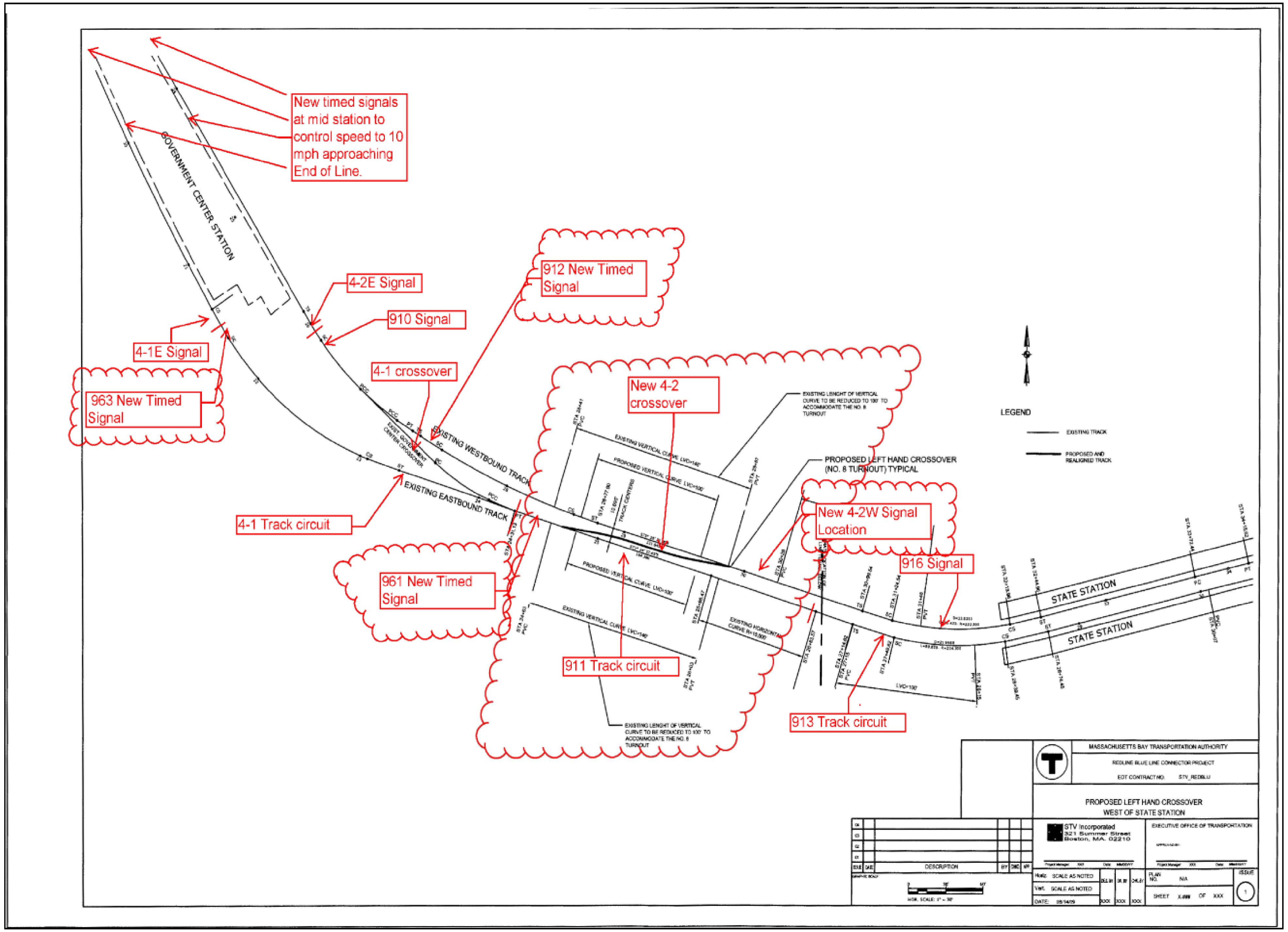


Figure 6-3 Government Center Interlocking with Changes

6.1.10 Boundary Between Construction and Government Center Station

Requirements for safe braking before the construction zone:

- 210 feet of clear track must be provided beyond the west end of the eastbound platform for safe braking before the construction zone. 219 feet must be provided beyond the west end of the westbound platform to provide safe braking.
- "Z", double red stop signals with trip stops will need to be installed at the west end of the Government Center platform on both tracks.
- Timed signals and trips will need to be installed in the middle of the platform tracks to limit the speed approaching the "Z" signals and bumpers to 10 mph.
- Due to the increased length of the 4 interlocking, timed signals will be required in the middle of the interlocking to control the speed of trains approaching the terminal location.

The new track circuits and signals shall be controlled from a new signal bungalow to be located adjacent to the existing signal bungalow.

6.1.11 Insufficient Space in Government Center Bungalow

During the Blue Line Signal Project all the Traffic relays for traffic between Government Center and Maverick and for traffic around the Bowdoin Loop were removed. This has created considerable rack space in the Government Center Bungalow which could be used for control of the new crossover. However, it is insufficient to control all the required new timed signals trips and track circuits. Therefore, a new vital processor controlled signal bungalow will be required at Government Center.

6.1.12 Direction of Traffic

The MBTA does not use reverse traffic between interlockings on the Blue Line. All Traffic circuits were removed with the Blue Line Signal Upgrade project.

There would not be room in Government Center Signal bungalow to re-install traffic relays for traffic control between Charles/ MGH and Government Center.

Based on the lack of space, STV does not recommend providing the ability to reverse traffic between Government Center and the new MGH interlocking.

6.1.13 Signal Aspects

The Blue Line uses the following aspects for automatic (non-interlocking) signals:

Table 6-3 Automatic Signal Aspects

Green	The signal is clear and so is the next one.
Yellow over Lunar White	This signal is clear and next one will clear after a preset time corresponding to the posted speed.
Yellow	This signal is clear but the next one is at stop
Red	The signal is at stop.

The Blue Line uses the following aspects for signals controlling the entry to an interlocking:

Table 6-4 Interlocking Signal Aspects

ASPECT	DEFINITION
Yellow over Red	The signal is clear and the switches are aligned and locked for a straight move.
Red over Yellow	The signal is clear and the switches are aligned and locked in reverse.
Yellow over Red over Lunar White	The signal is clear for a straight route and the next signal will clear after a preset time corresponding to the posted average speed.
Red over Yellow over Lunar White	The signal is clear and the switches are aligned in reverse and the next signal will clear after a preset time corresponding to the posted average speed.
Red over Red	Stop
Red over Red over Yellow	Call on Move. The switches are properly aligned and locked and the dispatcher has given permission for the move even though the exit track circuit is occupied. (Normally used at terminal locations and in yards.)

All the signal aspects listed in Table 6-4 will be required for the Westbound Signal at MGH.

The MBTA checks that the trip stop is at danger (up) before allowing a signal to clear. To increase safety it is recommended that the trip stop cycle check be moved to the control line of the previous signal to prevent it from clearing when a trip fails to come to danger when so commanded.

Where timed signals and relay timers are used, the back contacts of the timer are checked by the previous signal.

All automatic signals must have a "key-by" switch, a momentary pushbutton switch. The "key-by" switch allows the operator, with the permission of the dispatcher, to force a trip down to allow a train to pass a red signal in case of track circuit or other problems.

The MBTA generally uses wall mounted signals in the tunnel. Depending on the width of the tunnel and clearance, full height mast signals may be used.

The MBTA is using LED aspects for all new signals.

6.1.14 Signal Power Requirements

All signal equipment from the Government Center/Bowdoin Loop area to Orient Heights, including signal bungalows and signal cases, are powered from two redundant 480 VAC single phase power feeds from Aquarium Substation (Blue Line Eastbound Power and Blue Line Westbound Power).

There are switches at cases along the wayside to switch signal cases from one 480 VAC feed to the other. Signal bungalows have automatic transfer switches.

The Red Line/ Blue Line Connector Project will either utilize these power feeds or provide alternative redundant 480 VAC single phase power, phase synchronized with the Aquarium power. The new redundant 480 VAC single phase feeds are preferred at MGH.

6.1.15 Blue Line Track Circuits and Proposed Changes

MBTA uses 60 Hz AC track circuits on the Blue Line. Outside of interlockings, all track circuits are dual rail track circuits using AC vane relays and 0.25 ohm impedance bonds. Inside crossovers, single rail track circuits are used.

STV recommends changing from 0.25 ohm impedance bonds to 2.5 ohm tuned impedance bonds. While the 0.25 ohm impedance bond provides higher immunity to conductive emissions from traction inverters, this feature is not needed on the Blue Line. The worst case conductive emissions for Blue Line #5 cars are low enough that even with a 2.5 ohm tuned impedance bond emissions coupling into the track relay is well below one half the relay interference limit. STV recommends using a higher impedance tuned bond. The higher impedance bond will provide much improved shunting and the ability to allow longer track lead runs.

With 0.25 ohm bonds, the project would be forced to limit cable runs for the relay end of track circuits to 800 feet in order to limit track circuit currents to acceptable levels. With 2 or 2.5 ohm bonds the project could run all or almost all track circuit leads out of a single bungalow, reducing the need for wayside signal control cases.

Although the MBTA currently uses Alstom B2 vane relays and USS PV 250 relays on the Blue Line, STV recommends that the project use a non-vane relay solution such as the Safetran SE3[6] track circuit. The non-vane relay approach provides improved shunting, greater immunity to EMI, and reduced inspection requirements.

6.1.16 Interlocking Control Requirements

STV recommends the Red Line/ Blue Line Connector Project implements the MBTA's microprocessor based standard for all new interlockings. Redundant vital processors in hot or warm standby configuration for interlocking control should be used.

All track circuits in an interlocking must have 5 second loss of shunt timers.

All trips at the entrance to the interlocking must be at danger before a switch can unlock and move.

Standard route locking and approach locking logic must be employed.

This project should continue the MBTA policy of moving to electronic switch controllers instead of relays for switch control.

The MBTA uses NX (entrance/exit) logic to setup routes and call signals.

6 The SE3 will require the use of a tuned impedance bond.

Due to the fact that the OCC software communicates with signal bungalows using GERTU protocol, all non-vital logic including NX logic must be performed by GE Fanuc or compatible PLC's. STV recommends the use of redundant GE RX7 PLC's or approved equal for non-vital logic functions. The PLC's should be set up in a hot standby configuration. The PLC's must communicate with the vital processors via redundant serial links.

The status of track circuits and trips controlled from remote signal cases must be reported to the MGH or Government Center PLC's through case mounted Genius I/O modules, connected to the signal bungalow with 100 ohm twisted pair cable.

For interlockings, the MBTA Blue Line Signal upgrade project has provided redundant HMI servers serving a local control panel and a maintainer's panel located in the bungalow and a remote starter's panel located in the station. The PLC's, the HMI servers, the local control panel, the maintainers' panel and the starter's panel are all linked by a redundant local Ethernet network. The local Ethernet Network is linked through redundant switches to the Blue Line Ethernet Fiber Network. The HMI servers on the Blue Line Ethernet Fiber Network are set up so that maintainer's panels and local control panels in any location on the Blue Line can view any other location. In addition, any location can be controlled from a remote control screen in the Airport Blue Line Backup Control Center. The Red Line/ Blue Line Connector Project should continue this design for the MGH interlocking and extend the Blue Line Ethernet Fiber Network to MGH.

Each PLC at the new interlocking will communicate with the Operations Control Center (OCC) and the Remote Operations Control Center (ROCC) through dedicated fiber modems. In accordance with the rest of the Blue Line, the OCC will have default control of the interlocking. Local control of the interlocking may be assumed at any time through the local control panel without handshaking.

As terminal locations MGH and the new Government Center Bungalow will be required to have an automatic mode of operation. In this mode the setting up of routes into and out off MGH is triggered by an automatic ring off from the Operations Control Center (OCC), or by a train approaching the interlocking. The interlocking control should also have a local automatic mode in which the movement of trains is controlled on a fixed timed basis or train approaching the interlocking.

- The automatic control of the interlocking should be implemented in non-vital PLC ladder logic rather than in vital logic. The automatic logic will also control "Next Train" signs on the platform.
- In the automatic mode, the interlocking routes should be set up for the incoming train or the ring off train on a first come, first serve basis, unless of course, both platform tracks are occupied.

A "call on" signal shall be provided to allow trains to move into the platform area with platform or the track circuit behind the platform occupied. The "call on" move must be requested by the operator and enabled by the dispatcher. In order to allow storage of a train in a tail track during revenue service, the tail track must be at least 620 feet long. This will allow the required vacant track circuit between the platform and the stored train.

6.1.17 Operations Control Center

The PLC's in the signal bungalows communicate with the OCC via fiber modem.

- It will be necessary to obtain two fiber strands for OCC communications on the Red Line fiber network at Charles/ MGH Station. If this is not possible new fiber cable may need to be run.
- Two Fiber modems will need to be installed at the OCC.
- Terminal servers and switches will need to be configured to route the MGH communications to the Blue Line Server at OCC

Software modifications will need to be made in the Government Center PLC's to handle the new track circuit configuration.

Software modifications will need to be made for the Blue Line Server, for the Blue Line dispatcher's workstation, for the OCC database, and for the overhead displays.

STV recommends that the field PLC modifications be made by the Signal Contractor.

STV recommends that the OCC software changes be made by MBTA Signal Division which is familiar with the software and its source code.

6.1.18 Switch Machines

The MBTA Blue Line uses US&S M23 Switch machines. These switch machines should be used for the MGH interlocking to simplify maintenance, inventory and training.

6.1.19 Signal bungalow

The Signal bungalow should be located on the wayside within 500 feet of the farthest switch, be steel enclosed to provide protection against electromagnetic interference, and have dimensions of at least 40 feet by 10 feet, similar to the Wonderland bungalow. It should also have sufficient HVAC capacity to maintain a 70 degree ambient internal temperature in the hottest part of the summer, and the HVAC unit should be mounted externally to the signal bungalow and be designed to withstand a large amount of rail dust.

The Signal bungalow should be provided with:

- Redundant 480 volt single phase signal power, phase synchronized with the Aquarium signal power transformer.
- An automatic transfer switch, to switch from one signal power source to the other in case of power failures.
- An isolation transformer to step down 480 VAC single phase signal power to ungrounded 120 VAC inside the room to provide track circuit and signal control power.
- 230 VAC or 480 VAC and step down transformers from the station power system for HVAC, overhead lighting, and convenience outlets.
- Redundant 24 volt and 12 volt battery chargers to power vital and non-vital controllers, and signals. The 24 volt and 12 volt systems must be ungrounded.
- Battery capacity to maintain operation of vital processors, relays, PLC's, modems and HMI panels for 6 hours in the event of signal power failure.
- Entrance racks with gold nut links and insulated locking nuts.
- A fire suppression system.
- Shock mounted racks for mounting relays, track circuit equipment, vital and non-vital processors, computers, power conversion equipment and local control and maintainer panels and networking equipment.
- An MBTA MACom radio with EDACS and ProVoice and an external antenna, operating on Blue Line channels.
- A telephone line and two handsets connected into the MBTA internal phone system.
- Two doors with locking handles and emergency interior release.

6.1.20 Signal Control Lines

Single break signal control lines are currently used in the Government Center area of the Blue Line, however the MBTA is using double break control lines for all new construction. STV recommends that the Red Line/ Blue Line Connector Project use double break control lines for all signals involved in this project including those starting out of the Government Center Bungalow.

6.1.21 Wayside Cases

The existing signal design on the Blue Line uses wayside signal cases for powering track circuits and for housing the relays controlling each signal and trip stop in the areas between interlockings.

It would be desirable from a maintenance standpoint to reduce the use of wayside signal cases and to control as many signal cases as possible from the new signal bungalow. Using LED lamps for signal aspects and tuned impedance bonds, it should be possible to power all signals and track circuits aspects from the new Signal bungalow. However, powering the trip motors would limit cable runs to about 1500 feet.

Signals and trip stops up to the proposed location of the new Bowdoin Station could be powered from the MGH Signal bungalow. If a new Bowdoin Station is included in the project a large case or a small room could be installed in the Station to house the remaining track circuit, signal and trip controls. If a new Bowdoin Station is not included in the project, individual signal cases would be needed for signals more than 1400 feet from the MGH Signal bungalow.

6.1.22 Cables

The signal cables in the tunnel on the Blue Line are suspended from messenger cable mounted on the tunnel walls. This practice should be continued for the Red Line/Blue Line connector project.

Signal cable and signal power cables must be of low smoke, zero halogen design.

Signal cables may not be spliced. All connections must be made in approved AAR signal cases or junction boxes. Connections must be made on AAR terminals with gold nut links.

Cables passing under tracks must be protected in steel conduit located at least 30 inches below top of rail.

The following cable sizes are normally used by the MBTA:

- Signal aspect lighting, 12-conductor, 14 AWG.
- Trip control 12-conductor, 14 AWG. (For longer cable runs at least 3 #12 AWG conductors should be included in the cable for trip motor control.)
- 15-conduct cable (12c#14, 3c#6) should be used for switch control.
- Track leads, 6 AWG twisted.

Government Center Turn Back Safe Braking Design and Analysis

This section summarizes the safe braking requirements for the turn back at Government Center during tunnel construction. The analysis is based on MBTA signal design criteria in which the braking distance from each signal is calculated based on the assumption that the train accelerates at maximum acceleration toward the signal starting from the allowed speed for the previous timed signal. The train brakes to a stop after getting tripped at the signal at 75% of the worst tested emergency brake rate. An additional 35% of the braking distance is added to account for adhesion problems due to failed greasers or inclement weather. Based on these criteria clear track must be provided 219 feet beyond the West end of Government Center Platform for the westbound track and 210 feet for the eastbound track.

The possibility of using energy absorbing bumpers to reduce the braking distances during the construction phase and at this location has been explored. Based on feasibility and the safety compromises involved, STV recommends starting construction at the location indicated on Vol.III Drawing T-101 of 53.

6.1.23 Safe Braking Model

The MBTA uses a safe braking model that accounts for worst case operator error, 25% brake failure and low adhesion. The model assumes that the train accelerates with full power after passing the previous timed signal at the appropriate speed. A power removal time and brake build up time is allowed for about 1 second after the train is tripped at the signal that is violated. During this time the train essentially continues at the trip speed. After this point the train brakes at 75% of the worst tested emergency brake rate for that speed until a stop. To account for adhesion 35% plus twice the overhang between the trip and the coupler face is added to the braking distance. This then becomes the safe braking distance.

In the case where the concern is running into a bumper rather than another train one need only add one overhang distance. As a result 5 feet was subtracted from the required distances predicted by the safe braking calculator.

The safe braking model is particularly restrictive at low speeds due to the rapid acceleration of the train at these speeds. Speeds rise very quickly between signals and the braking distance goes up as the square of the speed.

6.1.24 Timed Signals

Seven new timed signals are required in order to control train speeds and provide safe braking from all signals on the approach to the tunnel construction site.

Timed signals are required in the middle of the Number 4 interlocking:

- A normal direction signal on the westbound track.
- A reverse direction signal on the eastbound track located between the two crossover legs.
- A timed signal will be required on the eastbound track opposite the 4-1E signal. (Signal 910 already exists opposite 4-2E on the Westbound track.)
- Two timed signals will be required on each platform track to enforce speed limits approaching the construction site.

6.1.25 Signals

Permanently red Z signals with trips permanently at danger are required just beyond the 6 car train stop point for each platform track. On the Eastbound track the Z signal must be placed 15 feet before the West end of the platform. On the Westbound track the Z signal must be placed 5 feet before the West end of the platform.

6.1.26 Control Lines

Control lines for all signals approaching are displayed in the attached drawing, Figure 1, Control Line Drawing.

In the control line drawings the blue (dashed) lines indicate the approach track circuit to the signal. The speed listed above each blue (dashed) line is the speed enforced by the signal timer. The end of the arrow indicates the distance that must be clear before the signal can clear. The allowable braking distance is the distance to the end of the previous signal's control line.

6.1.27 Safe Braking Results

The table below lists the results of safe braking analysis for each signal for the moves to the Westbound and Eastbound platform tracks. The analysis is based on 219 feet of clear track beyond the west end of the westbound platform and 210 feet beyond the west end of the eastbound platform. Signals in red type are new signals to be installed by the project.

The Safe Braking analysis was performed using the same model and MathCad worksheet that was used for the recent Blue Line Signal System Upgrade.

Table 5-5 Braking Results

- Minimum buffer Allowed is 35%

Westbound Braking Results

Signal	Stationing	Trip spd 4	Brk D. 4	Buf 4	Trip spd 6	Brk D 6	Buf 6	Min Buf %
961	130896	25.5	310.9	516.0	25.3	296.4	530.6	166.0%
963	131174	31.6	401.8	147.2	31.3	399.4	149.6	36.6%
965	131315	25.0	256.3	151.7	25.2	259.8	148.2	57.0%
967	131435	22.7	210.2	77.7	22.7	213.0	75.0	35.2%
969Z	131505	19.3	156.3	61.6	19.3	160.0	57.9	36.2%

Eastbound Braking Results

Signal	Stationing	TripSpeed 4	Brk Dist 4 car	Buffer 4 car	Trip speed 6	Brk Dist 6 car	Buffer 6 car	Min Buffer %
912	130963	28.8	371.0	329.9	28.2	356.7	344.2	89%
910	131099	26	282.4	282.5	25.6	284.1	280.9	99%
910 A	131269	26.2	280.3	114.7	26.6	289.6	105.4	36%
910 B	131382	22.2	207.1	74.9	22.3	209.2	72.8	35%
908 Z	131447	18.6	153.2	63.8	18.6	155.1	61.8	40%

6.1.28 Bumper Alternative

Energy Absorbing Bumper

One method of reducing the required braking distance is to use an energy absorbing bumper. There are two issues with a bumper solution: A bumper cannot be built in this location and to avoid injuries the bumper would have to be 35 to 50 feet long. Even if a bumper could be built, there are still safety compromises. If the bumper can safely stop a fully loaded 6 car train, the deceleration rate will cause injuries when struck by lightly loaded 4 car train. Based on the evaluation of safe braking analysis and the above issues, STV does not recommend the use of energy absorbing bumpers.

6.1.28.1 Conclusions

Impact on Tunnel Construction

Providing adequate safe braking distance will have a major impact on the routing and construction of the new tunnel from Government Center to MGH. The start of the tunnel must be located 250 feet from the end of the Government Center Platform.

Energy Absorbing Bumpers Are Not Recommended

Energy absorbing bumpers cannot be installed on the curved track and would be a safety compromise compared to the longer braking buffer.

Impact on Signal System Design

The large number of new signals required to meet the stringent safe braking requirements will make it mandatory to install a new vital processor controlled Signal bungalow at Government Center. There simply is not enough room in the existing bungalow for all the new signal controls.

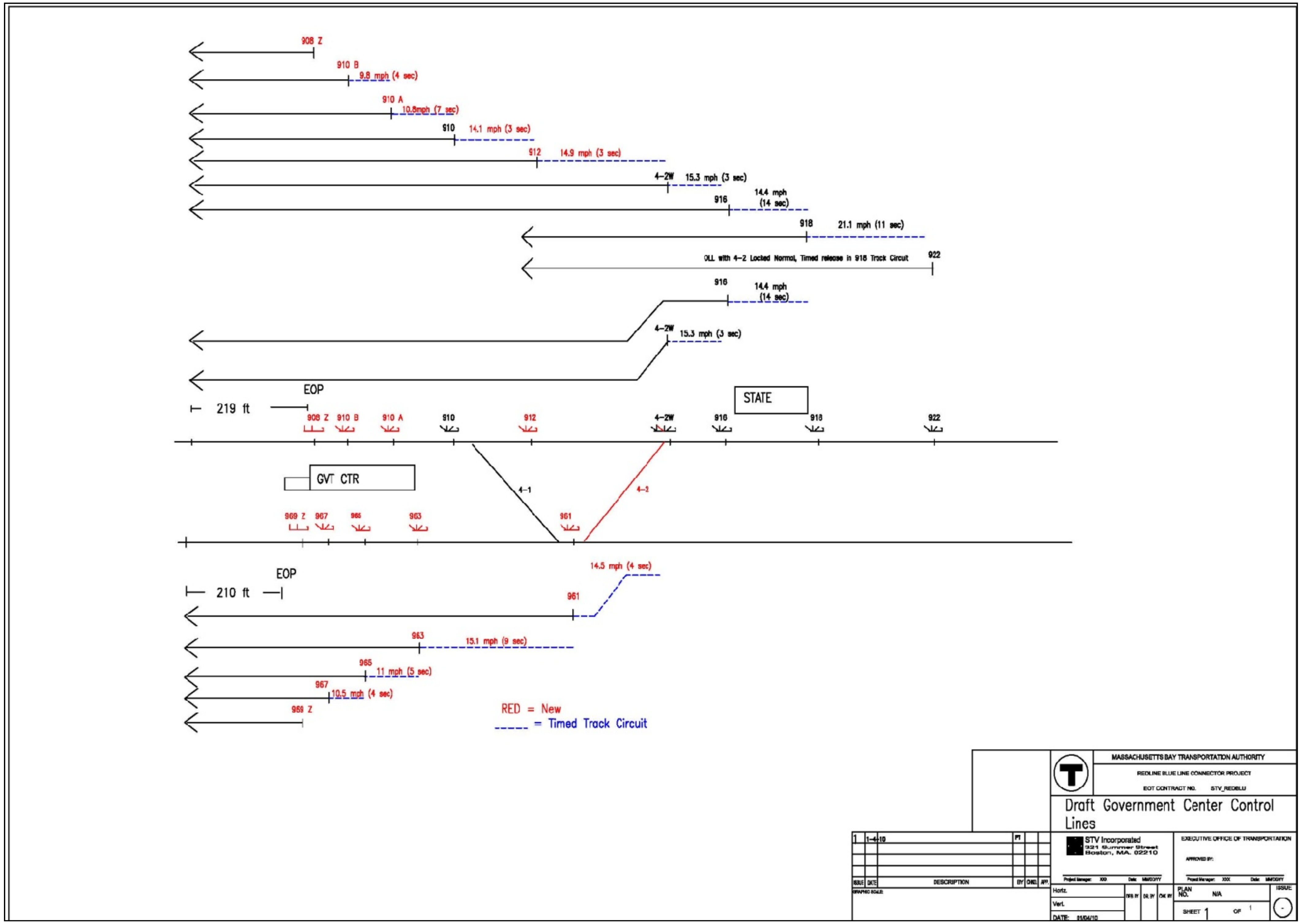


Figure 6-4 Government Center Control Lines

Communications

The purpose of this section is to describe the conceptual design of the Communications Systems for the Red Line/ Blue Line Connector Project (The Project). This section and the accompanying drawings shall serve as a basis of design for the planned communications systems installed on Massachusetts Bay Transportation Authority (MBTA) properties located along the proposed alignment. Currently, there are two alternative plans:

- Alternative 1: Red Line/ Blue Line Connector with Elimination of Bowdoin Station
- Alternative 2: Red Line/ Blue Line Connector with Relocation of Bowdoin Station.

This section shall identify strategies for providing Communications Systems conceptual designs for both alternatives. The work will consist of relocation of existing services, providing for disruption of existing services and the provision of new services at the facilities. The conceptual designs rendered shall comply with MBTA communications initiatives and strategies.

6.1.29 System Description

The communications systems for the MBTA provide vital support to the Authority's day-to-day operations and emergency services. The communications systems are designed to be integrated throughout the entire MBTA system, including stations, tunnels and ancillary areas. Therefore, designing and integrating a new communication system requires a comprehensive understanding of the MBTA existing and planned systems.

The proposed alignment for the Project includes the construction of a new tunnel, a new station platform underneath the existing Charles/ MGH Station, and the relocation of Bowdoin Station. At a minimum, this alignment requires the following communications systems:

- Fiber Optic Communications System
  - Wide Area Network (WAN)
  - Local Area Network (LAN)
- Wireless Systems
  - Radio
  - Commercial Cellular
- Public Address / Electronic Signage System (PA/ESS)
- Telephone System
  - Wayside Telephones
  - Passenger Assistance Units
- Security Systems
  - Closed Circuit Television (CCTV)
  - Access Control System
- Hub Monitoring Control System (HMCS)/SCADA
- Fare Control System

The conceptual design requirements for each of these systems are discussed in the subsequent paragraphs.

6.1.30 Fiber Optic Communications System (FOCS)

The MBTA has an existing FOCS network designed to provide data transport for system elements along its Red, Blue, Green, Silver, and Orange Lines to the Operations Control Center (OCC). Any modifications or upgrades to the network by the designer for this project shall ensure compatibility with the existing network.

6.1.31 Wide Area Network (WAN)

The communications system design shall interface to an existing backbone data transmission network. This transmission medium is a synchronous optical network (SONET) conforming to the ANSI T1.105 SONET standards.

The Project interfaces to the SONET shall operate at the highest communications system transmission rate in operation on the MBTA at the time of design. Lucent OC-12 SONET (622.08 Mbit/s) nodes currently exist at both Charles/ MGH and Bowdoin Stations. For Charles/ MGH Station and Alternative 2, the design will include new SONET nodes at each station. Each new node will be designed to be incorporated into the existing SONET ring as specified by the MBTA.

The Communications systems designer shall perform a bandwidth analysis of all new equipment to verify that there is enough capacity, including 100% spare capacity for future considerations. If there is not enough capacity, coordination is required with the MBTA to provide additional bandwidth to the location.

The communications system design shall interface with the MBTA system-wide network management system (NMS), including all additions and modifications, relative to the Red Line and Blue Line.

6.1.31.2 Local Area Network (LAN)

A LAN for network connectivity for the station systems is required. The LAN also serves as an interface point to the Lucent OC-12 SONET node. The currently approved LAN network switch is the CISCO Catalyst series.

The project designer shall require the Contractor to work with the MBTA's IS staff to setup and configure the Ethernet switch including VLAN configurations and Quality of Service (QoS). At a minimum the contract shall be required to setup the VLANs to support the Automatic Fare Control (AFC) system, the CCTV system, and the HMCS system, plus a minimum of two additional systems.

6.1.32 Wireless Systems

6.1.32.1 Radio

The MBTA radio system recently went under a major overhaul to upgrade its capacities. The new system is an 800MHz digital, trunked Radio system, comprising of 15 voice and 5 data channels. The radio system is the M/A-COM EDACS. The system supports two-way, land-mobile communication with capabilities to operate in analog mode for existing Low Density Data (LDD) systems in order to support the legacy Boston Police Dept. (460 MHz) and the Boston Fire Department (483-486 MHz).

For this project, a link budget analysis shall be performed to determine if enough signal strength can be achieved from an interface to the bi-directional amplifier (BDA) existing at Government Center Station. The BDA currently feeds the 800 MHz and 400 MHz antenna system at Bowdoin Station. For Alternative 2, this antenna system will be expanded and reconfigured to provide coverage to the new station layout.

The new station platform located underneath Charles/ MGH will require a completely new distributed antenna system comprised of free space antennas and radiating cables. Depending on the link budget analysis, the antennas will be fed from a RF splitter/combiner or from a new BDA installed in the communications room.

Two radiating cables, 1 for transmit and 1 for receive, are required in each of the new tunnels. These cables will be fed from the BDA at Government center or from the new BDA installed in the Charles/ MGH communications room.

6.1.32.2 Cellular

A separate tunnel cellular antenna system is not required to be included in the communications design. The assumption is made that the tunnel cellular infrastructure will be paid for and installed by a cellular provider, as is common in the industry. If this service is included, space will be required in the tunnels for radiating coaxial cable, discrete antennas, and base stations/repeaters. In the station areas, a separate room approximately 12′ x 12′ shall be set aside for cellular base station equipment. This room shall have its own access door into the public areas for private entry by the cellular vendor. This space shall be set aside for the future use of the tunnel cellular system provider.

6.1.33 Public Address / Electronic Signage System (PA/ESS)

The Station PA/ESS for the new stations under this project shall receive, amplify, monitor, and distribute (via loudspeakers and electronic variable message signs), announcements originating remotely from the Announcement Control System at OCC workstations, and locally from local microphone stations and a Station Public Address Computer.

The Station PA/ESS system shall be configured for a minimum of 3 zones (inbound, outbound, and mezzanine). Additional zones to be added as specified on the contract drawings. Zones shall consist of both electronic variable message signs and loudspeakers. Electronic signs shall be located in accordance to ADA requirements.

All PA/ESS loudspeakers shall be configured to supply a Speech Intelligibility Index averaging 0.60 or greater over at least 90 percent of their target coverage areas, on a per zone basis. However, in no location regularly occupied by the public shall the Speech Intelligibility Index be less than 0.45. The Speech Intelligibility Index shall be determined according to the methods set forth in ANSI; Methods for Calculation of the Speech Intelligibility Index. The PA/ESS shall include an Ambient Noise Analysis System that will automatically change the volume level of the Public Address System dependent on the amount of the ambient noise level at the station.

Each zone of speakers shall consist of two circuits of alternating speakers A and B. The Station PA/ESS shall be configured so that equipment and wiring failures related to circuit A shall not affect the operation of circuit B. Each circuit shall carry half the speaker load per zone.

The PA/ESS installed under this project shall fully integrate, interface and function with the ARINC PA/ESS Head End hardware and AIM software system installed at the Operations Control Center (OCC), which includes all local station maintenance and diagnostic functions, both local and remote monitoring.

The maintenance functions shall include but not be limited to:

- Remote monitoring and configuration of public address Digital Signal Processor (DSP),
- Public Address power amplifiers,
- Preamplifiers,
- Station Control Units (SCU),
- Electronic Signs.

- The Station PA/ESS shall be a fully integrated system. The system shall use a local Station Control Unit (SCU) configured with AIM PA/ESS software to manage and control all station functions and hardware including:
- Microphone page stations and associated queuing,
- Telephone interfaces,
- Distribution of emergency announcements,
- Local announcements,
- OCC announcements,
- Recorded announcements,
- Pre-recorded and assembled messages,
- Visual display paging.

6.1.34 Telephone System

For analog circuits, the MBTA utilizes a Verizon Centrex service at each station. This service is required for the new communications rooms at Charles/ MGH and Bowdoin Station under Alternative 2. No more than 3 telephone units shall be connected to a single circuit for this project.

6.1.34.1 Wayside Telephone System

Wayside telephones will be located along the tunnel walls every 500 feet and will interface to the main distribution frame (MDF) in the nearest communications room. The wayside telephones shall be two-line phones suitable for a transit tunnel environment and shall support an emergency auto-dial function. Blue lights are required to be installed alongside the wayside telephones.

6.1.34.2 Passenger Assistance Units

Passenger assistance units shall be specified for the public areas of the new Charles/ MGH Station and the new Bowdoin Station under Alternative 2. The units shall be compatible with the existing Emergency Intercom Supervisory System located at Authority's Police Station at 240 Southampton Street and with the Authority's maintenance terminal located at 500 Arborway. The audio path between the Station, the Police Station and Hub Centers shall be via Verizon analog Centrex telephone service.

Locations of intercom units shall conform to the Americans with Disabilities Act (A.D.A.) standards. The Intercom Units shall be microprocessor based, programmable, flush or wall mount, no handset, full-duplex speaker telephone with a front panel of stainless steel. The Emergency Intercom Unit shall be fully A.D.A. compliant as specified in ADAAG 4.10.14 and ASME 17.1. The Intercom Units shall have the ability to record and playback two separate voice messages.

Coordination of any modifications to databases/software that are utilized in conjunction with the Passenger Assistance units is required.

6.1.34.3 Analog Telephones

Two line desktop analog telephones and single line wall/desktop analog telephones are required for installation in ancillary rooms of the new Charles/ MGH Station and the new Bowdoin Station under Alternative 2. The phones shall interface with the MDF in the communications room.

Security Systems

The security systems located at the stations shall be comprised of the CCTV System and Access Control System. New station security systems are required for Charles/ MGH Station and the new Bowdoin Station under Alternative 2.

6.1.35 CCTV System

MBTA recently upgraded its CCTV systems with the Automatic Fare Control (AFC) project. Video cameras and digital viewing/recording systems haven been deployed as a part of this project, primarily to monitor the automated ticketing machines, ticket portals, and entry gates. The system incorporates analog CCTV cameras and Digital Video Recorders Servers (DVR/S), video encoders/decoders and any other hardware and software required to transmit/receive video over an IP network.

The design includes DVRs and RAID storage units to be installed in the Communications Rooms. The DVRS shall encode the video signals from the analog CCTV cameras. The DVRS shall record local station video feeds to limit the amount of video traffic transmitted over the WAN. The video shall be transmitted and stored using MPEG-4 compression standards. The DVRS shall also have the capability to transmit video simultaneously over the WAN to other users. It shall be possible for any user on the WAN to access video feeds and display them within a web browser. No additional software shall be required to be installed. The web browser interface shall have camera PTZ control.

The system shall be a real time video system working in conjunction with the Hub Center Digital Video System. “Hub” centers are employed at strategic locations within the rail subway system. Each of these locations is accessible over the MBTA WAN. The Hub Centers shall have full capability of viewing live and recorded video from any combination of cameras that are part of the project. The hubs provide the custom service agent(s) with video views for security and AFC system monitoring. The design for this project shall include any modifications/expansion necessary at the Hub locations.

The Hub Centers shall have the capability of viewing video feeds and display the video on the LCD monitors. Hubs exist at the following locations:

- Hub 1 – South Station
- Hub 2 – Airport
- Hub 3 – Back Bay
- Hub 4 – 10 Park Plaza
- Hub 5 – Harvard
- Hub 6 – North Station
- Hub 7 – Operations Control Center (OCC)

6.1.36 Access Control System

The access control system shall consist of Lenel proximity card readers, magnetic door locks, reader modules, and a system controller. All doors providing access to private areas shall be equipped with access control devices. The design will include sufficient memory to support the maximum number of authorized users as specified by the MBTA.

The system controllers shall be wall mounted in the communications rooms and shall interface with the MBTA WAN. The system controllers shall be compatible with the existing Lenel Server head-end located at the OCC in order to receive updates and authorized personnel credentials.

6.1.37 Hub Monitoring Control System (HMCS)/ SCADA

The SCADA system design shall provide the means for remotely effecting the monitoring and control functions required by the Power and Traction Power substations, the Ventilation plants, the Fire, Life Safety, and Security systems and other MBTA systems in the tunnels and stations including the escalators, elevators, and TGH gates.

A new SCADA cabinet will be installed in the new communications room at Charles/ MGH Station and in the new communications room for the relocated Bowdoin Station under Alternative 2. The cabinet will house a communications programmable logic controller (CPLC) consisting of I/O blocks, CPU, Ethernet communications module, and a remote I/O communications module for interfacing to remote I/O blocks within the station and ancillary areas. A UPS will be provided to provide backup power.

Each vital circuit shall be connected to at least two of these PLCs. The SCADA system shall be compatible with the system(s) in use on the MBTA, both at the time of design and at the time of future system modifications. All Human Machine Interface (HMI) screens shall have the capability to be viewed via Cimplicity's Web Client software.

The Hub Monitoring and Control System (HMCS) is a control and monitoring hub for station security, elevator, escalator, generator, fire alarm and trouble indications and miscellaneous alarms that are located throughout the station. The AFC hub locations are identified in the previous section.

Communications Rooms

In order to support computer hardware, software, networking, telecommunications, and video equipment at the stations, communications rooms will be included in the design. There are existing communications rooms at Charles/ MGH Station and Bowdoin Station which have reached capacity. New communications rooms are required for this project at each site. The approximate size for the rooms is 20' X 20'.

The communications room will consist of a main electrical load panel to power the air conditioning (A/C) unit, lighting and an uninterruptible power supply (UPS). A UPS load panel will provide branch circuits to each rack and communication devices mounted on the walls. Systems equipment will be installed in this room inside 19" EIA standard equipment racks. FM-200 clean agent flooding system is required in each communications room. A relay shall be provided to interface the FM-200 with the Fire Alarm System.

All network and voice cabling within the communications room will utilize Cat6 rated and tested cables, connectors, and junction boxes. All data cabling entering the communication room shall enter a cable tray for distribution to the associated rack or terminal board. The fiber optic cable shall conform to the MBTA standard for single mode fiber 62.5/125um. All cables will be clearly marked at each end, displaying cable number and cable type in a clearly visible tag. A complete set of certification tests will be performed on each cable and the results documented and returned to MBTA as part of the final contract.

The communications room grounding system shall be designed to provide safety to personnel and to protect equipment. The communications ground grid shall consist of ground rods and conductors, and shall be designed so the step-and-touch potentials at the maximum available fault current are in accordance with IEEE 80. The communications room grounding design shall be in accordance with MBTA practices.

6.1.38 Design Requirements

This section describes the minimum design requirements that are to be incorporated into the design of the communications systems for this project.

6.1.38.1 Codes and Standards

All design work and material selection for any new communications systems shall conform to or exceed the requirements of the latest editions of standards and codes issued by the following organizations:

- Americans with Disabilities Act (ADA)
- American National Standards Institute (ANSI)
- American Society for Testing & Materials (ASTM)
- Federal Communications Commission (FCC)
- Institute of Electrical and Electronics Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)
- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Telecordia
- Underwriters Laboratories (UL)
- Applicable State, Local, and County Codes
- MBTA Guidelines, Specifications and Procedures

6.1.38.2 Reliability, Maintainability, and Availability

Performance of the communications systems shall be measured in terms of MBTA standards for reliability, maintainability and availability (RMA). RMA metrics shall be established for the communications systems such that they are never the limiting factor in the RMA performance of the overall Red Line or Blue Line. Extensive factory testing of fully assembled individual systems shall be required before components are released for shipping.

6.1.38.3 Project Interfaces

The communications systems of this project are directly or indirectly associated with many other systems and other project activities. A communications system shall be provided that is fully interfaced with these other project activities and that performs all required functions. Additional required interfaces shall be identified and a recommendation made for the most effective method of their control. The interface descriptions in this Section are not complete in detail, but are meant to be used in conjunction with communications drawings and other Chapters of the Design Criteria. The following list includes areas of potential interface that shall be taken into consideration.

- Civil facilities, such as provision of equipment rooms, conduits, duct banks, etc.
- Electrical and mechanical facilities such as power supplies and HVAC
- Ventilation and drainage systems for monitoring, control and emergency response purposes
- Corrosion control and grounding systems for grounding of equipment
- Fire/life safety systems for monitoring, control and emergency response purposes
- Traction power systems for monitoring, control and emergency response purposes
- Signaling systems for monitoring and control purposes

- Fare vending systems for data communications purposes
- Public switched telephone network, including public pay telephones
- The City of Boston emergency services

6.1.38.4 Electromagnetic Compatibility

Communications equipment and systems shall be specified that use industry standard practices and techniques for suppression and mitigation of both radiated and conducted electromagnetic interference (EMI/RFI). "Industry standard" in this context refers to practices and techniques sanctioned by the radio communications, telecommunications, data communications and information technology (IT) industries.

The equipment shall meet the EMI Immunity requirements as specified by Telcordia standard GR-1089-CORE, criteria 15 to 19, which covers the requirements for the ability of the equipment to operate properly when subjected to electric fields and conducted RF signals on AC and DC power leads.

These practices shall include the implementation of appropriate shielding, grounding, bonding and electronic filtering methods and specialized wiring and cable installation practices. These suppression and mitigation techniques shall be sufficiently employed so that EMI/RFI does not prevent the communications systems from achieving their specified RMA goals. Similarly, the communications systems emissions shall be sufficiently managed or suppressed such that no other reasonably protected system within proximity of the communications systems will be prevented from achieving its specified RMA goals.

6.1.38.5 Environmental Requirements

Interior equipment to be installed within the MBTA environmentally controlled buildings shall be designed and certified by the manufacturer to operate in a range of from minus 15 degrees to plus 35 degrees Celsius (C) with a relative humidity of 20 percent to 80 percent, non-condensing. Heating and air conditioning of any computer rooms will be provided as required.

6.1.38.6 Equipment Grounding

The equipment shall meet the Grounding and Bonding requirements as specified by Telcordia standard GR-1089-CORE, criteria 74-93 that addresses multi-point grounding, AC and DC equipment grounding, types of connectors and short circuit fault currents.

Power System

The Red Line / Blue Line Connector will terminate in a passenger station below the existing Red Line Charles/ MGH Station. The Traction Power electrical needs of the extension will be met by a new double ended traction power substation and possibly two double ended unit substations. The traction power substation will be built below ground at the mezzanine level in the vicinity of the new passenger station. Power for the traction substation will be provided by the MBTA's 13.8kv network of AC cables that pass through the area of the new station. The MBTA will benefit from this decision to feed the traction power substation from their power source because of the backup power system they have at South Boston. If power was lost to the system they can provide backup power to get the trains out of the tunnels and run on a reduced headway. Traction power for the new mainline 3rd rails and the storage tracks will be powered from here. Power for the unit substations will come from four 13.8kv breakers in the new traction power substation. There will be two 480 volt, three phase feeders coming from the unit substation to provide "house" power for the traction power substation. See Appendix C – Traction Power Analysis, Load Flow Study.

6.1.39 Existing Conditions:

The MBTA's Blue Line power system consists of 5 traction power substations. They are located at Wonderland (40), Orient Heights (22), Airport (4), Aquarium (12) and North Station (14). Four of these traction power substations feed just the Blue Line and the associated carhouse at Orient Heights. They are Aquarium (12), Airport (4), Orient Heights (22) and Wonderland (40). Wonderland, at the east end of the line, receives its AC power feed for the traction power substation from National Grid at 24kv. The other 4 traction power substations are fed from the MBTA's 13.8kv network. In case of a complete power failure to the MBTA's power system, the MBTA can power up their system from the gas turbine generation facility at South Boston. This will allow them to move the trains out of the tunnels and run the system on a reduced headway.

Each of the traction power substations has a minimum of 2 incoming AC feeders and 2 rectifiers. North Station is the only station to have 3 rectifiers so it can handle the loads of the Orange, Green and Blue Line. North Station is running near its full load capacity now. Each traction power substation is equipped with a line up of DC Feeder breakers. This permits the MBTA to feed each revenue power section from 2 separate traction power substations as required per their design criteria.

6.1.40 Options:

Before the option to build a new traction power substation, three other options were considered. The three options are listed below and the salient points of each option are presented.

Option 1: Kendall Square Traction Power Substation No. 3

- The Kendall Substation has 5 – 13.8kv AC cables that feed in and out of the substation. There are nine traction power DC Feeder breakers being supplied power from three rectifiers with one unit presently out of service due to a transformer that will most likely need to be replaced. A 1997 load flow study indicates there is enough traction power to supply the extension of the Blue Line with all three rectifiers in operation. A new Red Line load flow study is being performed in preparation for a new fleet of vehicles. Implementing traction power feeds from Kendall substation will maintain the MBTA's requirement that all power sections be supplied by two different substations.
- At least four new DC Feeder breakers will be needed along with 4 – 1000mcm and 8 – 2000mcm power cables. The cables will be installed over the Longfellow Bridge through the existing Charles/ MGH Station to the new Red Line Station below.
- The number of open ducts for additional DC cables is not sufficient. A new duct line will be needed with 100% spares to meet MBTA requirements. The number of new ducts will be 24. These ducts will be made with 4" FRE conduit. This duct bank would come out of Kendall Substation and then along the Red Line via the Longfellow Bridge to Charles/ MGH Station and down to the new Blue Line track area.
- The approximate distance from Kendall Substation to the third rail connection points in the new tunnel is over 4,300 ft. The price of new power cables alone would be over $1,500,000. Adding the price of a new duct bank, new switchgear needed in the traction substation and the installation costs would make this option very costly.

Option 2: North Station Substation No. 14

- The North Station Substation has 7 – 13.8kv cables that feed in and out of the substation. There are nineteen traction power DC Feeder breakers being supplied power from three rectifier transformer units. This station is heavily loaded supplying DC Power to the Orange Line, Green Line and Blue Line. Implementing traction power feeds from North Station substation will maintain the MBTA's requirement that all power sections be supplied by two different substations. Recent load flow studies indicate that the substation is reaching its load capacity. The loss of this substation would cripple all three lines.
- North Station currently supplies power to the Blue Line from two DC Feeder breakers and cables that connect to the third rails in the storage track area of Bowdoin Station below Cambridge Street. These cables then run up to Bowdoin Station through duct banks on both sides of the tracks.
- Four new DC feeder breakers along with 4 – 1000mcm and 8 – 2000 mcm power cables will be needed. North Station is a crowded substation with little room for additional DC breakers.
- The number of existing open ducts for additional DC cables from this substation is not sufficient. A new duct line will be needed with 100% spares to meet MBTA requirements. The number of new ducts will be 24. These ducts will be made with 4" FRE conduit. This duct bank would run down Canal Street to Causeway Street and up Staniford Street.
  The approximate distance from North Station Substation to the new Blue Line passenger station is approximately 3,200 feet. Duct banks in the new tunnel will be needed to bring power cables to the new station area. The price of new power cables alone would be over $ 1,200,000. Adding the price of a new duct bank, new switchgear needed in the traction substation and the installation costs would make this option very expensive.

Option 3: South Station Substation No. 31

- The South Station Substation has 2 – 13.8kv feeders. This station is fed a little differently than the others as 1 feed is from NStar and the other is from the MBTA's power system (0-31-1). There are twenty one traction power DC Feeder breakers being supplied power from (2) rectifier transformer units. A lot of these breakers are not in working order. Implementing traction power feeds from South Station substation will maintain the MBTA's requirement that all power sections be supplied by two different substations. The station is lightly loaded as it supplies power to two (2) power sections on each of the Orange and Green lines.
- Supply power from four DC breakers and install 4 – 1000mcm and 8 – 2000mcm cables in the Red Line tunnel to Charles Street Station to the Blue Line Station below.
- The equipment in the station is past its expected life cycle. The substation was built in the mid 70's and is in need of a major overhaul to bring it up to today's standards. There are some newer breakers (Whipp & Bourne DC Breakers) but they were installed about 20 years ago, they are of the open faced type and most have been out of service for over 10 years.
- Duct space in the Red Line tunnel is very questionable. A new duct line will be needed with 100% spares to meet MBTA requirements. The number of new ducts will be 24. These ducts will be made with 4" FRE conduit. This option is the most expensive of the three options due to the length of the cables needed, the age of the substation and the difficulty of installing duct banks and power cables in the Red Line subway.
- The distance from South Station Substation to the new Red Line Station is approximately 5,000 ft. The price of new power cables alone would be over $1,800,000. Adding the price of a new duct bank, new switchgear needed in the traction substation and the installation costs would make this option very expensive.

Proposed Charles/ MGH Traction Power Substation

The construction of a new "Charles/ MGH Traction Power Substation" in the vicinity of the new Red Line Station will do the following:

- A new traction power substation will be a far more reliable source of power for the MBTA than the three options listed above.
- Reduce the load at North Station traction power substation by eliminating the two feeder breakers that feed the Blue Line.
- Maintain the MBTA's requirement to feed the revenue power sections from 2 different traction power substations.
- Provide 2 separate power sections for the storage tracks
- Will provide power to the third rails through much shorter power cables. Shorter cables mean less cable maintenance.
- The new substation will be in a central location among the MBTA's rapid transit lines.
- The new substation will include the latest in traction power equipment.
- Existing valuable manhole and duct line space will not be used up.
- The cost savings in not having to install a considerable amount of expensive new power cables, duct lines and new DC breakers will help pay for the new substation.
- The use of Kendall Substation (the best of the 3 other options) and the installation of new cables and ducts may conflict with the reconstruction of the Longfellow Bridge.
- Without the traction power substation, additional equipment or a switching station would be needed to route the 13.8kv cables into the two new unit substations.
- Auxiliary power for back-up systems will be available from a new substation that may not be available from the other three options.

All design work and material selection for a new substation shall conform to or exceed the requirements of the latest editions of standards and codes issued by the following organizations:

- American Railway Engineering Association (AREA)
- American National Standards Institute (ANSI)
- American Society for Testing & Materials (ASTM)
- Institute of Electrical & Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- Insulated Cable Engineers Association (ICEA)
- American Society of Mechanical Engineers (ASME)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- National Electrical Testing Association (NETA)

- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- Applicable State, Local, and County Codes
- MBTA Plans, Specifications and Procedures.

The traction power portion of the substation shall be double ended and will include two incoming AC breakers, two traction power breakers, one tie breaker, and two complete sets of traction power transformers and rectifiers and a negative drainage board. See attached drawing TP 1. The DC distribution switchgear will have a common bus fed by the two rectifiers. The loss of one AC feeder, a power transformer and or one rectifier from either side shall have no impact on train operations. Train service shall be maintained with the loss of a substation. The DC distribution switchgear shall continue to operate as an equalizing tie station with the DC circuit breakers closed.

A load flow study of the new Blue Line Extension will be run to simulate the operation of the Blue Line vehicles in this area. This study will look at the operations from Airport Station to the new Charles/ MGH Station. This study is presented in Appendix C, Traction Power, Load Flow Study.

The extension of the Blue Line will add approximately 1600 ft. of double main line tracks and two storage tracks for one 6 car train each. Trains will receive traction power from a system of third rails, wayside switch boxes and power cables.

6.1.41 AC Switchgear

The AC Switchgear line up shall be metal clad, self supporting arc resistant switchgear with draw out type breakers rated at 15kv. The two incoming feeder breakers shall be interlocked with each other and the bus tie-breaker between them. The ground and test devices shall be designed not to be seen as a regular breaker when racked into any of the AC cubicles to prevent conflicts involving the interlocking system.

Power to the substation will come by splitting either one of the three 13.8kv cables between the South Boston Switching Station and the Kendall Traction Substation. All three cables run in the same duct bank through Charles Circle before crossing the Charles River. The cable chosen will be cut in the manhole and both ends of the cable will be extended to the new traction power substation. This will provide 2 AC Cables to feed the new traction power substation. One feed will be from South Boston Switching Station and the other feed will come from the Kendall Traction Substation.

The AC switchgear line-up shall have positions for the following assigned breakers with Bowdoin eliminated; incoming lines; 2 positions, traction power; 2 positions, unit substations; 2 positions, bus tie; 1 position and 1 spare position for a total of 8 AC breakers or with Bowdoin relocated; incoming lines; 2 positions, traction power; 2 positions, unit substations; 4 positions, bus tie; 1 position and 1 spare position for a total of 10 AC breakers. See attached drawings TP-02-1 & TP-02-2. The unit substation is to supply house power to the traction power substation.

The power circuit breakers shall be of the nominal 13.8kv class, three phase, with vacuum interrupters on rollout frames rated according to ANSI C37.06 as follows:

Table 5-6 Power Circuit Breakers

Nominal three phase MVA	750
Rated Continuous Current	1200 Amps
Rated Maximum Voltage	15.0kv
Rated Voltage Range Factor	1.3
Rated Withstand test voltage	
Low Frequency (rms)	36kv
Impulse Crest	95kv
Rated Short Circuit Current	

at Maximum voltage (rms)	28 ka
Maximum Symmetrical	
Interrupting Capability (rms)	36 ka
Three second Current Carrying	
Capability (rms)	36 ka
Closing and Latching Capability	
(rms)	58 ka

The AC Switchgear in the substation shall include an MBTA approved ground and test device (GTD) with viewable contacts and no vacuum bottles. An umbilical controller may be used to open and close the “ground and test device” with a time delay built in. The time delay device will be on the “GTD” and will be in the close circuit no matter where the close signal originates from. The GTD will not be controlled by the supervisory system. The supervisory system may get an indication that the GTD is racked in and closed. The GTD will have stabs to ground either the bus or cable side of the switchgear although only one will be grounded at a time. Test ports and removable test stabs are to be included.

6.1.42 DC Switchgear

The DC side of the traction power substation shall include two rectifier transformers, two rectifiers, DC switchgear line-up, a negative drainage board and wayside disconnect switches and cables. This equipment shall function as a complete, coordinated package for unattended operation within the MBTA’s traction power system.

The DC switchgear line-up will include 9 positions which will be assigned as follows: two DC rectifier cathode breakers, 4 DC feeder breakers for the new power sections, 2 spares and 1 DC breaker to feed three manually operated fused disconnect switches to be located at one end of the DC switchgear line-up. These switches may be used to feed back-up passenger station and tunnel lighting and DC pumps in the tunnels. See Volume III for TP drawings.

An epoxy floor will be installed to isolate the DC traction power equipment from all grounds. Successful testing of the epoxy floor and floor anchors must be completed before any part of the DC switchgear can be installed.

The DC switchgear shall be metal clad, with draw-out type feeder breakers, equipped with metering equipment and an auto reclosing systems. The auto reclosing system will be designed to limit the number of attempts to reclose the breaker after which a trip signal will be sent to the breaker. The rate of rise relays and other load sensing equipment shall be able to discriminate between high resistance faults and train starting currents.

The DC lineup will include an auxiliary cubicle to house control wiring, AC reliable supply equipment, switchgear alive or grounded protective relays, annunciators and recording equipment. The Auxiliary cubicle may house the local control switches and meters for the AC line-up.

DC traction power cables will be either 1000 or 2000 mcm, insulated rated to 1000 VDC minimum and DC spikes of 3000 volts. Cables supplied shall meet the requirements of the MBTA Power Department specifications P-118,119,120 and 121 for both positive and negative cables. “Positive” cables may be used in place of “negative” cables. Due to the low demand for “negative” cable it is now more expensive than the “positive”.

The negative drainage board will be a free standing metal enclosed panel to include the negative equalizer bus, the negative leads from the rectifiers, connection points for traction power return cables, cables from the isolated bus in the AC switchgear and utility drainage cables. The cables from the isolated bus and the local utilities will have shunts to measure possible stray DC currents, diodes to prevent a possible back flow onto these cables and contactors that will open if both rectifiers are open. An isolation amplifier (IA) takes raw data from the shunts for telemetering of stray current levels back to the SCADA System. The negative bus from each rectifier will connect to the equalizing bus through a kirk keyed controlled manually operated disconnect switch with an annunciator indication. (DEVICE 89N).

6.1.43 Rectifier Transformers and Rectifiers

- Rectifier transformers will be indoor, dry-type, self-cooled, with primary voltage to be consistent with the incoming AC supply (13.8kv) and equipped with appropriate taps. The transformer/rectifier shall be designed so that the maximum overall regulation is not greater than six (6) percent +/- 0.5 percent.
- Rectifier transformers and rectifiers shall be designed to withstand overloads of 150% for two hours, 5 equally spaced periods of 300% for 1 minute during the two hour period and 450% for 15 seconds at the end of the two hour period. Overloads will be applied after constant temperature has been reached following continuous operation at full load.
- Rectifier transformers shall be built for "extra heavy traction service" per NEMA RI-9 ANSI C57.18.10 (Circuit 31) and IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers.
- The rectifier shall be silicon diode type, natural convection-cooled. The rectifier shall be a complete operative assembly consisting of the diodes, heat sinks, internal buses, interphase transformer connections, diode fuses, and all other necessary components and accessories. It shall consist of a full-wave bridge providing 12-pulse rectification. An auxiliary compartment will be attached to house control wiring, protective relays and an annunciator panel.
- Transformers and rectifiers shall be equipped with interlocked door switches that will trip the 86 lock out relay when a door that may lead to energized equipment is opened. A complete open, close and lock out scheme will be developed for each rectifier / transformer unit.
- Disconnect devices which do not have load-break capabilities shall be equipped with interlocks (Kirk Keys) to prevent unsafe operations. A system of kirk key locks are to prevent the opening of one of the rectifier negative ground switches until the corresponding rectifier DC breaker has been removed from its cubicle. Removing the kirk key from the lock will prevent the rectifier DC breaker from being racked back in.
- Rectifiers and DC switchgear shall be isolated from earth ground and shall be equipped with monitoring devices which detect and annunciate the breakdown of insulation between the enclosure and ground, and between the enclosure and traction power positive potential. Breakdown of insulation between the enclosure and positive traction power shall also cause power to be removed from the unit affected.
- A control / auxiliary compartment will be attached to, but completely isolated from the rectifier. This compartment will house the associated control wiring, instruments and devices to monitor and control the rectifier transformers, rectifiers and the main DC breaker.
- The rectifier annunciators will be solid state type with back-lit nameplates consisting of 30 to 36 alarm positions. The annunciators shall be rated for operation on the 125 VDC control power system. Each will have three push buttons to acknowledge, reset and test each alarm. The annunciators shall be insulated from the rectifier enclosure for a minimum of 1000 volts DC. All alarm points for which the alarm contacts are remote from the rectifier and all retransmitting contacts shall be wired to outgoing terminal blocks for connection to field wiring. (Device 30)

6.1.44 Control Power

Control power will be provided by the substation's 125 VDC control battery system to include batteries designed for switchgear service, a properly sized battery charger, a 125 VDC distribution panel and accessories. The station batteries will connect to the distribution panel through the main breaker while the battery charger will connect to the distribution panel through a branch circuit breaker. The battery charger shall be capable of operating as a "filtered battery eliminator" to operate as a DC power supply without batteries.

The batteries will be housed in a separate room with its own ventilation system to prevent a buildup of explosive gases in the room. The batteries will be rack mounted with spill containment and an absorption system below. The charger will be located outside the room along with an eye wash system.

6.1.45 SCADA

The supervisory control and data acquisition (SCADA) system provides a continuous remote monitoring and control of essential substation equipment. Equipment in the substation will include remote terminal units for the SCADA System and the 1 on 1 backup system, supervisory terminal boards (STB), and the cables to the different points in the substation. Any new system must be compatible with the existing system and its backup and meet the requirements of MBTA Power Department Specification P-139.

The following define the minimum key substation functions for remote control and monitoring:

Control:

- AC Breakers,
- DC Breakers
- Motor operated Disconnect switches

Monitoring:

- AC Breaker Status, open, closed, tripped by protective relays
- DC Breaker Status, open, closed, load measuring (102)
- Supervisory Control, on, local, off
- Ground and Test Device, installed, open, closed
- Rectifier Transformer Temperature Status, alarm, trip (49T)
- AC Overvoltage
- AC Under Voltage
- DC Voltage (Analog)
- DC Overvoltage
- DC Under voltage
- DC Over current
- DC Rate of Rise (150)
- Load Measuring Timed Out
- DC Cable Alive (197)
- Intrusions
- Fire Detection
- Auxiliary Power
- Uninterrupted Power System/Battery
- Substation Ambient Temperature
- Ground Current
- Rectifier Annunciator Alarm Summary (74R1, 74R2,)
- DC switchgear Alarm Summary (DC1)
- Station Battery Voltage
- Battery Charger Failure
- Circuit Breaker lockouts
- Local Remote Control Switch Position (43)
- Sump Pump
- Rectifier Transformer Temperature Alarm
- Substation Ventilation

Substation Grounding

The substation grounding system shall be designed to protect the safety of anyone in the substation and protect the equipment in the building. The substation ground grid shall consist of a system of ground rods and interconnected cables (4/0 minimum, hard drawn bare copper cables thermite welded) so the step and touch potentials at the maximum available fault currents are in accordance with IEEE 80 and MBTA's best practices.

6.1.46 Traction Electrification

The traction electrification system shall be capable of supplying the transit vehicles during periods of maximum transit density. The system shall be designed to enable operation of AW3 "Crush Loaded" trains with the maximum number of cars at minimum headways. Under normal conditions, the traction electrification system shall supply sufficient power to enable the trains to achieve the maximum allowable speed and acceleration rates subject to the maximum current draw limit of the trains. The lowest voltage at any train shall be maintained above the minimum value. The traction power system will also be expected to supply up to three- six car trains parked / stored in the area of the new station with a fourth 6 car- train leaving the station. The minimum headway will be 4 minutes.

The DC Power distribution will be a double ended feed type where the electrical continuity between the adjacent substations is provided through the 85 lb. composite third rail system and distribution cables where available. In the event of the loss of one complete substation, continuity shall be maintained through the DC switchgear in the inactive substation or through the trackside sectionalizing switches and the third rail.

The automatic re-closure procedure after a fault may include opening of the associated DC breakers in the adjacent substation. The automatic re-closure procedure shall be limited to an MBTA determined number of attempts before the breaker is sent an automatic trip command through the SCADA system. In the event the breaker 43 selector switches is set to "local" the DC breaker will have the means to limit the number of times it attempts to reclose.

The mainline tracks shall be electrically independent from each other and the storage tracks. See attached TP drawings for the proposed new power sections for the extension of the Blue Line. Also see Volume III - TP drawings for the proposed power sections with the elimination of Bowdoin and the proposed power sections with Bowdoin relocated.

DC Circuit Breakers and motorized/manual load sectionalizing and isolation switches will be used to isolate sections of the third rail. The load sectionalizing and isolation switches shall be used to further isolate sections of third rail in the event of faults and or for maintenance purposes.

Manual disconnect switches shall be an open knife blade design, unfused, made of solid copper, front mounted, connected and operated. The switches will be housed in a lockable fiberglass enclosure with a back board for mounting purposes. The arrangement of the switches will be according to the contract drawings. Wayside disconnect switches are to meet the requirements of the MBTA's Power Department specification P-150 "Feeder Isolation Switches 2000 and 4000 amps".

The negative return system for the storage tracks shall not be grounded during normal operations but provisions shall be provided by means of a grounding switch to automatically ground the return rails should the rails reach an unsafe level of voltage with respect to ground. The return rails of the mainline shall be electrically isolated from earth and meet the minimum resistance to earth criteria as defined in corrosion control criteria for stray current protection.

Traction Power for maintenance facilities shall be electrically separated from mainline and storage traction power. The negative return system shall be grounded through properly sized surge arrestors in the traction power substations at the negative drainage board.

Provision shall be made to provide for emergency interconnection of storage traction power feeds with the mainline power supply system through manually or electrically operated wayside switches.

Traction power cables (DC) from the substation to their third rail connection points and between gaps in the third rail shall be installed in FRE conduit in concrete duct banks. Manholes should be spaced approximately every three hundred feet to limit the lengths of individual cables and make it possible to run side feed taps to switchboxes. Provisions shall be made to limit the exposure of these cables once they have left the substation.

The duct bank system is to be extended on each side of the new tunnel to tie into the existing system of 2 over 2 ducts. The duct lines and manholes shall meet or exceed the requirements of MBTA Power Department specifications P-153 for the "Construction of Underground Conduits and Manholes" and P-180 for "Fiberglass Reinforced Conduit- Interior Use".

6.1.47 Proposed DC Power Relocation for Construction

The MBTA requires power sections be supplied by two separate power substations, for redundancy purposes. While evaluating this area we used the MBTA's E-Plan, E- 20. DC Power supplied to a power section should be connected at either end, from 2 separate traction power substations for voltage drop considerations. This becomes more important in continuous rail type of construction. When a six car consist traveling in a power section that has another consist traveling in the same power section at the same time this could create a low voltage situation. This would increase the current, possibly causing damage to the train's electrical system and the traction power system in general. That's why a load flow study was done so the design of the traction power system will be able to handle the load without any power issues.

For this proposal the Aquarium end of traction power sections T1A and T2A will not be discussed, as they will not be impacted by this project. The existing conditions at the Bowdoin end of traction power sections T1A and T2A will be discussed. They consist of 4-2000 mcm positive DC cables from North Station traction substation via Staniford St, 2-2000 mcm positive DC cables to section T1A via switch L/964 and 2-2000 mcm positive cables to section T2A via switch L/963. There are also 2-2000 mcm negative return cables from North Station traction substation via Staniford St, that connect directly into the Blue Line negative return system, which consist of 2-2m negative return cables, one for each section T1A AND T2A.

During construction the Bowdoin Station will not be in service. The storage track will become part of the construction project and could be grounded, at the discretion of the MBTA and the contractor. The Blue Line will stop at Government Center. The addition of a crossover just before Government Station will allow the MBTA to cross trains in a timely fashion to maintain a good operating system. The new cross over will be fed from the existing 3rd rails in the proper power sections.

PROPOSAL #1

This proposal would include:

The construction of a new 3 x 3 duct bank with nine 5 inch FRE fiberglass conduits encased in reinforced concrete routed alongside the construction area, from mh 2622 on Stanford St., up Cambridge Street. to an area above the niche at mh1350. This manhole is located at the west end of Government Station platform on the eastbound side of the Blue Line.

Install 9 reinforced cement encased FRE conduits down to the niche at manhole 1350.

Install 3 new 5" rigid steel conduits with fiberglass inserts from mh1349 to mh 1350 in the ballast, under the tracks.

Install 2-2m positive feeders from mh2622 to mh1350, cut & splice into cables 14035X & 14035Y in mh 2622 with 2mx2m straight joints, and GVT-BP3 &GVT-BP4 in mh 1350 with 2m x2m x2m wye type splices.

Install 2-2m positive feeders from mh2622 to mh1349, cut & splice into cables 14034X & 14034Y in mh 2622 with 2mx2m straight joints, and GVT-BP1 &GVT-BP2 in mh 1349 with 2m x2m x2m wye type splices.

Install 2-2m negative return cables from mh 2622 to the ballast between mh's 1349 &1350, cut and splice into existing returns in mh 2622 with 2mx2m straight joints and splice into the existing returns in the ballast with 2m x2m x2m wye type joints. Disconnect boxes BJ/913 and BJ/920 third rail taps and insulate for possible future use.

Install a 2m negative return cable from the ballast at mh 1452 on the Blue Line to the ballast at mh 1371 on the Green Line and connect all working returns together with insulated joints. This will insure a return path back to North Station Traction Substation in the event of a failure of the return installed previously.

Removal of all electrical switchboxes and cables would be required west of Government Center Station to the end of the tunnel at Bowdoin storage tracks, with all switchboxes turned over to the MBTA. NOTE: This proposal should be coordinated closely between the Engineers, Consultant, Contractors and the MBTA to avoid any conflicts during construction.

PROPOSAL #2

This proposal would include running four 2m positive feeders and two 2m negative return cable down to feed the Government Center Station end of power sections T1A and T2A. The work would involve:

Utilizing the existing breakers at South Station Traction Substation, and the existing cables down to the Red Line vault at South Station.

Four new 2m positive feeders and two 2m return cables would have to be run from the South Station vault down the Red Line to manhole1332, then up to manhole 1336, down Otis St. and Devonshire St. to manhole 42A, then down to the Blue Line at State Street Station to manhole T57.

Two 2m positive cables and one 2m return cable will go to mh 1452 then connect the two 2m positive cables to the existing station by-pass cables GVT-BP-3&4 with 2m x2m x2m wye type joints.

Two 2m positive cables and one 2m return cable will cross the tracks to manhole T46 and go to mh 1453 then connect to the two 2m positive cables to the existing station by-pass cables GVT-BP-1&2 with 2m x2m x2m wye type joints.

The two 2m return cables in mh's 1452&1453 shall be run to the ballast, and connected to the existing two 2m returns in the ballast with 2m x2m x2m wye type joints, making a complete circuit, using insulated joints.

GVT-BP-1,2,3&4 may have to be cut and live capped in mh's 1347 & 1452, dependant on the limits of construction.

Install a 2m negative return cable from the ballast at mh 1452 on the Blue Line to the ballast at mh 1371 on the Green Line and connect all working returns together with insulated joints. This will insure a return path back to North Station SS in the event of a failure of the return installed previously.

Removal of all electrical switchboxes and cables would be required west of Government Center Station to the end of the tunnel at Bowdoin loop, with all switchboxes turned over to the MBTA. NOTE: This proposal would have to be thoroughly surveyed for availability and viability of the existing manholes and duct banks to be used.

Proposal #1 would be the preferred option as the condition of the duct bank going down the route outlined in Proposal#2 is unknown.

The New Blue Line Vehicles

The new Blue Line vehicles are equipped with regenerative breaking. The system is designed for natural reception only. The traction power electrification system shall be designed using the parameters defined below:

Table 5-7 Traction Power Electrification System

Nominal System Voltage	600 VDC
Maximum System Voltage	750 VDC
Train Propulsion Change	530 VDC
Minimum System Voltage	500 VDC
Maximum Rail to Ground Voltage, normal	50 VDC

The location of a traction power substation is going to be in the mezzanine level of the new Charles/ MGH Station.

Storm Water Management Layout

Storm drainage will be provided throughout the new tunnel. Due to the slope of the proposed tracks from Bowdoin Station area to Charles/ MGH, the pumping station pit for the storm water pumps will be located at the tunnel low point near Charles/ MGH. The pump pit will be provided with airtight hatches to prevent the spread of odors from the storm water. The pump pit will also have hoist rails to aid in the removal of pumps if replacement is required. Additional drainage pits may be required depending on the final profile of the tunnel.

Structural Design

6.1.48 Design Criteria

The basic design criteria established in this chapter shall govern the design of all structures for the MBTA Red Line/ Blue Line Connector.

6.1.49 Codes

The following codes, manuals, and specifications shall be utilized in the structural design, unless otherwise specified herein.

- "State Building Code of the Commonwealth of Massachusetts, Seventh Edition, 2009 referred to in these criteria as "State Building Code".
- "Building Code Requirements for Structural Concrete, ACI 318-08 of the American Concrete Institute., including its commentary.
- "Standard Specifications for Highway Bridges", Seventeenth Edition of the American Association of State Highway and Transportation Officials 2002 referred to in these criteria as AASHTO Bridges.
- "Standard Specifications for Highway and Bridges ", 1988, of the Massachusetts Highway Department, referred to in these criteria as "MHD Specifications".
- "Allowable Stress Design of Manual Steel Construction", Ninth Edition, 1989 of the American Institute of Steel Construction, revision 1991, referred to in criteria as "AISC Specifications".
- Building Code Requirements for Masonry Structures, (ACI 530 / ASCE 5 / TMS 402).
- "Manual for Railway Engineering", of the American Railway Engineering and Maintenance of Way Association, 2002, referred to in these criteria as "AREMA"
- MassDOT Bridge Manual

6.1.50 Guidelines for General Structures

The design of the following structures shall also use the guidelines and codes indicated herein:

Structures Carrying Highways Traffic or Buses

The design of structures carrying general highway or supporting the MBTA bus traffic shall be in accordance with "AASHTO Bridges" as modified by MassDOT Bridge Manual.

Above Ground Structures

The design of above ground building and stations not subject to moving loads shall be in accordance with the following:

- State Building Code
- AISC Specifications (Steel)
- ACI 318 (Concrete)

Underground Structures

The design of Underground Structures shall be in accordance with the Standard Specifications for Highway Bridges.

6.1.51 Future Construction

Unless specifically directed by the MBTA, no provisions for any future construction will be made.

6.1.52 Loads

Dead Loads (D)

Dead loads shall consist of the weight of the complete structure and all material permanently fastened to and supported by it.

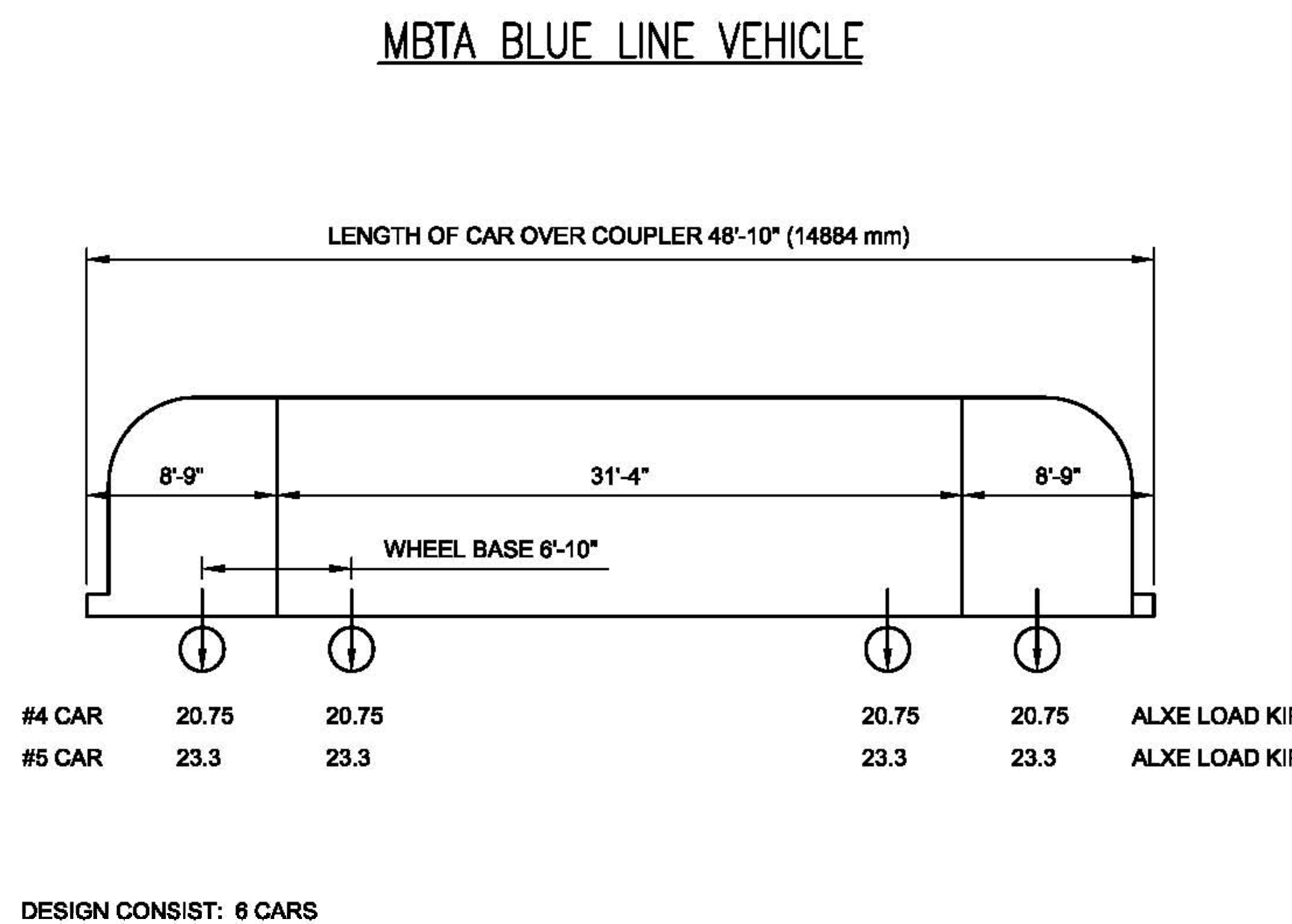
Live Loads (L)

Live Loads shall consist of any non-permanent loads, including weight of machinery, equipment, stored materials, pedestrian, motor vehicles, transit vehicles, elevators, escalators, construction loads, and loads due to maintenance operations.

Moving vehicle loads shall be applied to produce the most critical conditions for axial, bending, shear and torsional stresses, deflections and stability. Structures shall be designed for MBTA #5 Blue Line Vehicle and Work Train Loading whichever governs.

6.1.52.1 MBTA Blue Line Car and Work Train Loading

Design axle, loading and spacing shall be as shown in MBTA No. 5 Blue Line Vehicle Figure below. Structural loading shall be applied to produce the most critical conditions for axial, bending, shear and torsional stresses, deflections, and stability. Axle loads on track ties, or direct fixation to be uniformly distributed longitudinally over no more than 7½ feet when on a 115 pound RE rail.



6.1.52.2 Highway Vehicles

For structures carrying general motor traffic or MBTA buses, the design loading shall be in accordance with "AASHTO Bridges", Section 3, HS25. The HS25 loading system shall be determined by using the Standard HS20-44 Truck and Equivalent Lane Loading configuration and increasing all corresponding loads by 25 percent.

6.1.52.3 Floor loads

The minimum uniformly distributed live loads on buildings, stations and miscellaneous structures shall be in accordance with the Massachusetts State Building Code, except as modified herein:

Table 5-8 Distributed Live Loads on Buildings

Service Walks, Stairs & Escalators	0 psf
Platforms, lobbies and Concourse floors	150 psf
Floors of maintenance areas & Ventilation Rooms	250 psf
Floors of electrical equip., Relay & Signal Rooms	250 psf
Storage spaces	250 psf

Table 5-9 Gratings:

In roadways & sidewalk areas	AASHTO HS20-44
Sump pumps & Interior areas	50 psf or 200# over area 1'x1'
In other areas	100 psf or 500# over an area 2'x2'

Table 5-10 Railings and Barriers:

In places of Public assembly	"State Building Code"
Vehicular Railings	AASHTO Bridges

All equipment areas to be checked for actual equipment loading.

6.1.52.4 Impact (I)

For design of those structures or structural elements listed below, the vehicle loading shall be increased for dynamic, vibratory and impact effects.

Application

Use dynamic, vibratory and impact loadings for superstructure, including steel or concrete supporting columns, and generally those portions of the structure which are above the main foundation slab.

Not Applicable

- Abutments, retaining walls, wall type piers & piles
- Foundations & footings
- Safety walks, stairways, station platforms or other pedestrian areas
- Culverts and structures having a cover of 3 feet or more
- Invert slabs resting on earth.

6.1.52.5 Vertical Impact Force (Iv):

Impact considerations for bridges shall be in accordance with Article 3.8 of "AASHTO Bridges". The impact factor shall be applied to vehicle loading.

Design of the top slab of underground structures supporting roadway loading shall conform to the following:

Table 5-11 Underground Structures Supporting Roadway Loading:

Up to 1' earth cover	IV=30%
>1' to 2' earth cover	IV=20%
>2' to 3' earth cover	IV=10%
>3' earth cover	IV=0%

The depth of cover shall be measured from top of ground or paving to the top of the underground slab or structure.

6.1.52.6 Transverse Horizontal Impact Force in MBTA Blue Line Car (Ih)

Provisions shall be made for transverse horizontal impact force Ih equal to 10 percent of the Blue Line car loading. This force shall be applied horizontally in the vertical plane containing each axel and shall be assumed to act, normal to the track, through a point 3.0 feet above the top of low rail.

Centrifugal Force (CF)

Provisions shall be made in the design of the transit roadway invert slab for the centrifugal force as specified in "AREMA" and "AASHTO".

6.1.52.7 Wind (W)

Above ground structures shall be designed to withstand wind forces in accordance with the "State Building Code".

Earth Pressure (E).

6.1.52.8 Vertical loads

Loads on underground structures shall be as outlined in Appendix B. In the absence of more precise date and for preliminary design, use the values given below.

The vertical loads on underground structures shall be computed using depth of soil cover times the unit weight of compacted soil.
Assumed unit of weights of soil are as follows:

Table 6-12 Assumed Unit of Weights of Soil:

Existing soils & Backfill	120 pcf
Submerged Soils	58 pcf

6.1.52.9 Permanent Horizontal Loads

The permanent horizontal loads on structures shall be using the "at rest" earth pressure coefficient Ko.

6.1.52.10 Ground Water

Ground Water elevation is based on CA/T datum which is 100' below USC & GS mean sea level datum of 1928.

For permanent conditions:

Max El. 108.0 (or as per Appendix B)

6.1.52.11 Loads from Adjacent Buildings

Both live and dead loads within the zone of influence of underground structures shall be considered. For loadings see Appendix B.

6.1.52.12 Surcharge (S)

A vertical surcharge shall be applied at the ground surface over & adjacent to all underground structures. This surcharge or highway vehicle loading shall be used, whichever is more critical. This surcharge includes the AASHTO surcharge of 2'-0" and makes allowance for any future developments. The surcharge intensity shall be determined as follows:

Table 5-13 Surcharge Intensity:

For x=0 to 5' depth:	S= 600 lb/sf
For x 5 to 14' depth:	S= 600-40(x-5) lb/sf
For x= over 14'	S=240 lb/sf

Where:

- S= Vertical Intensity of surcharge at depth x
- X= Depth below ground surface

This surcharge shall not be additive to:

- Highway vehicle live load.
- Specific, applicable building surcharge

A lateral surcharge load of 300 lbs/sq ft for a depth of 0 to 20 feet and 150 lbs/sq ft for a depth of 20 to 40 feet shall be used for all conditions.

6.1.53 Earthquake Forces (EQ)

Seismic design for buildings and above ground structures shall be in accordance with the "State Building Code".

Seismic design for underground structures shall be in accordance with the "Seismic Design Criteria for Underground Structures, Appendix B of Section V of Project Design Criteria, Central Artery/Tunnel Project, prepared by B/PB Rev 5, December, 1992.

6.1.54 Temperature (T)

Provisions shall be made for movements and stresses resulting from temperature variations.

For underground structures, the normal temperature shall be taken as 55° F. The ambient temperature variation during construction shall be taken as plus or minus 25° F. The average temperature of all interior members of the completed structure shall be assumed to vary plus or minus 20°F.

For above ground structures the normal temperature shall be taken as 50°F. The expected temperature rise & fall shall be taken as follows:

Table 5-14 Expected Temperature Rise and Fall:

Concrete:	35° F rise and 45° F fall
Steel:	70° F rise and 80° F fall

Thermal effects shall use the following coefficients of expansion:

Table 5-15 Coefficient of Expansion:

Concrete:	0.0000060 inch/inch/F
Steel:	0.0000065 inch/inch/F

6.1.55 Shrinkage and Creep (SH)

Provisions should be made for movements and stresses resulting from concrete shrinkage and creep. The shrinkage coefficient shall be assumed to be 1.0002 inch per inch. For creep due to sustained load, the Modulus of Elasticity of the concrete shall be as given in “ACI 318”.

6.1.56 Buoyancy (B)

Buoyancy force shall be computed at 62.4 pounds per square foot per foot of depth below groundwater table.

Adequate resistance to flotation shall be provided at all sections for full uplift pressure on the structure foundation, based on maximum probable height of the water table. Provision shall be made in the design, or a construction sequence shall be specified, to prevent buoyancy which might result from a rise in water table before all backfill is completed.

6.1.57 Hydrostatic (H)

Design for Horizontal pressures due to the adjacent ground water table.

Structural Types and Foundations

6.1.58 Tunnel

Three types of tunneling methods are envisioned for the Project:

- Tunneling with Tunnel Boring Machine (TBM)
- Tunneling with Sequential Tunneling Method (SQTM)
- Tunneling with Cut and Cover Method (C&C)

6.1.59 Tunneling with TBM

The use of the TBM requires the construction of a starter hole and a receiver hole. The starter hole will be located just east of the existing Charles/ MGH Station and the receiver hole will be located near the existing Bowdoin Station. The TBM will be used to tunnel from the starting hole for the northerly (outbound) track to the receiver hole. Once it reaches the receiver hole it will be dismounted and transferred to the starter hole to tunnel for the southern (inbound) track in the easterly direction. All of the excavated material will be transported through the already completed tunnel shell to the staging area located at the present MEEI parking area between the off Ramp from Storrow Drive WB and the on ramp to Storrow Drive WB. The prefabricated concrete tunnel lining will be sent also form the staging area to the TBM for installation as the excavation progresses.

6.1.60 Tunneling with SQTM

The SQTM will be used for the construction of the two Storage Track Tunnels and also for the construction of the third arch over the new platform area and at the Cross over area just east of the new Charles/ MGH Red Line Station. The northerly Storage Track Tunnel will be constructed as one of the first priorities, because it will be used for transportation of excavated material from the TBM operations and delivery of the prefabricated concrete panels for the TBM bored tunnel lining.

6.1.61 Tunneling with C&C Method

The primary use of the Cut and Cover method will be at the eastern end of the Blue Line extension between the present Bowdoin Station and the eastern terminus of the project. At this section of the project the use of the TBM is not feasible due to the required demolition of the existing concrete tunnel structure. The temporary earth supporting system (slurry panels) will be located outside of the existing tunnel walls. As the excavation progresses, the existing tunnel walls and columns will be demolished as necessary. The remaining portion of the existing tunnel will be backfilled with flowable fill and prepared for the placement of the new invert slab. The walls of the temporary earth retaining structure will remain in place and will serve as permanent tunnel walls where feasible. The C&C Methods will also be utilized for the construction of the Ventilation Structure above the then already completed new Blue Line Tunnel at the North Anderson Street. The approximately 80 feet by 60 feet excavation will be supported by slurry walls, whalers and struts. The temporary slurry walls will be also used as permanent walls for this ventilation structure.

Pier Underpinning

Do to the closed proximity of the planed tunneling to the Red Line Pier Nos. 6 and 7, underpinning of these piers will be required.

Pier No. 6 underpinning will be provided with the installation of temporary pier support framing. Once the temporary framing is in place, the existing pier and pier cap will be demolished and a new minipile supported pier will be constructed.

Pier No. 7 underpinning will be made by the use of needle piles supported on new minipile foundations.

Foundation Design at the Existing Charles/ MGH Station

The foundation design of the relocated northerly exterior wall of the existing Charles/ MGH Station will be by the use of grade beams and minipiles similar to the present Charles/ MGH Station foundation.

Geotechnical Recommendations

The Geotechnical Interpretive Report- 10% Design Level (GIR) is presented in Appendix A of this report describes the tunnel excavation and soil testing, removal, and disposal requirements of the Project for both Build Alternatives. Permanent and construction period impacts from excavation and soil removal are summarized in this section.

Some ground settlement may occur as a result of dewatering along the tunnel alignment and in the area of Bowdoin Station to accommodate construction activities, as described in the GIR, Section 4.4.2. Settlement may affect some adjacent structures, depending upon the extent of dewatering and type of building foundation. Underpinning may be required to prevent permanent damage to some structures. Other buildings or structures (such sidewalks or retaining walls) may be monitored for settlement during construction, and repaired if damaged. There is no difference in risk of permanent settlement damage between the Build Alternatives.

The soil profile within the Project area includes fill, organic silt, marine clay, marines and, glacial till, possible glacial moraine deposits, and bedrock. Construction techniques have been selected based upon the geotechnical properties of the soils, taking into consideration the presence of groundwater. Both of the Build Alternatives involve a predominantly mined tunnel (using a tunnel boring machine) in combination with relatively short sections of tunnel constructed using the cut-and cover construction technique. The Charles/ MGH Station and Bowdoin Station (for Alternative 2 only) platforms, and tail track tunnel segments would be constructed using the sequential excavation method.

The estimated volume of soil that would be excavated by either Build Alternative is 175,000 cubic yards. The soil would be removed by conveyor and stockpiled at the construction staging area or directly loaded into dump trucks, trucked off-site and disposed of at an appropriate, approved site.

Contaminated soil or groundwater may be encountered during Project construction activities. Excavations to 65 feet below ground surface would likely be through contaminated soil, and dewatering activities (specifically in the vicinity of Bowdoin Station) may involve impacted groundwater. Exposure to residual hazardous materials in soil and/or groundwater may present a risk to worker health, and any materials with concentrations of chemicals in excess of regulatory standards must be treated and/or disposed of properly. A soil and groundwater management plan, describing testing protocols, on-site management, and eventual treatment or disposal would be developed. A preliminary plan, developed as a framework based on the current level of Project design, is provided in GIR, Appendix A.

Additionally, suspected lead, mercury, or asbestos-containing building materials, as well as polychlorinated biphenyl products and petroleum products, are present within Bowdoin Station and the existing tunnels. Construction or demolition activities may result in worker exposure to these regulated materials. The nature and extent of the exposure risk may vary between the Alternatives, depending upon the extent of construction material disturbance at Bowdoin Station. It is not possible, at this phase of the design, to determine the extent of materials that would be disrupted for either Build Alternative. A hazardous materials management plan, describing testing protocols, on-site management, and eventual treatment or disposal would be developed to the extent necessary, based upon the final design.

Mechanical

6.1.62 Emergency Ventilation

The main objective of the emergency ventilation system is to provide occupants with a smoke-free path of egress away from a train fire. This is best accomplished by means of a mechanical ventilation system which is capable of forcing smoke in the opposite direction of the path of evacuation. Fan chamber vent shafts are typically located between stations, ideally at either end of a station platform, and are designed to serve as both smoke evacuation shafts during an emergency and pressure relief shafts during normal operation. The requirements for emergency ventilation fans will depend on several factors, including which design alternate is chosen and the length, size and geometry of the final tunnel design.

Although determining the exact size and location of fan chambers and vent shafts will require further evaluation at a later stage in design, at this stage of the design, it is assumed that two new fan chambers and vent shafts will be required, one at the new Charles/ MGH Station and one at the intersection of Cambridge Street. and Sudbury St. Each shaft will be equipped with two tunnel ventilation fans (approx. 175,000 cubic feet per minute per fan), fan dampers, relief (bypass) dampers and tunnel dampers. Fans will be axial flow type, with an internally mounted, direct drive, reversible motor. These proposed vent shafts will serve to provide both mechanical ventilation and natural ventilation to the tunnel system.

At Charles/ MGH, the fan chamber will be located above the new tunnel structure, just beyond the east end of the station platform. Cut and cover techniques will be used to build the underground fan chamber, fan control room and associated electrical space once the new tunnel structure is in place. A vent shaft will terminate at grade in the median of Cambridge Street. and be covered with a metal grate.

To satisfy current design standards, which require emergency ventilation fans to be located no more than 2,000 feet apart, a fan chamber and vent shaft will also be provided at the intersection of Cambridge Street. and Sudbury St. A fan chamber, fan control room and associated electrical space will be constructed above the proposed tunnel structure using cut and cover techniques and a vent shaft will terminate in the median of Cambridge Street.

Because the location of a fire is unpredictable, it is necessary that the fans are reversible so air can be forced in whichever direction is most preferable at the time of the emergency. In the event of a vehicle fire in-between two stations, fans on either side of the fire would operate in a "push-pull" fashion, where the fans downstream of the incident would operate in exhaust mode and fans upstream would operate in supply mode. Similarly, if a fire emergency occurred in a station, fans located near the end of each platform would both operate in exhaust mode and fresh air would be drawn in through the station's entrances to provide a smoke-free path of egress.

The air velocity required to properly control the direction of smoke during a fire is known as the "critical velocity" and is a function of the rate of heat release by the fire, tunnel geometry, tunnel grade, vehicle size, ambient air temperature and other factors. If this critical air velocity is not met during a fire emergency, the effect of buoyancy may cause the hot products of combustion to travel in the direction of evacuation rather than the direction of forced ventilation. This phenomenon is known as "back-layering" and can interfere with the safe evacuation of passengers, as well block the path of ingress for fire fighters. Ventilation fans are sized to ensure the critical velocity can be achieved throughout the tunnel system.

To determine critical velocity, an engineering analysis is performed using computational fluid dynamics software that can model environmental conditions within tunnel systems. The fluid analysis model will simulate the airflow dynamics produced in a fire scenario and calculate the critical velocity required to prevent back-layering. This software will be used at a later stage of design to evaluate whether or not the fan locations proposed in this report will allow effective smoke control. The model will also be used to determine the exact fan capacity required to adequately remove smoke.

The volatile nature of a tunnel emergency requires a comprehensive communication and control system so that the responsible emergency personnel have the information required to make effective judgments. Emergency ventilation fans will be both locally and remotely controlled and connected to the existing emergency ventilation control system for the transit system. Emergency policies should include specific fan control strategies to guide emergency personnel during various emergency situations.

6.1.63 Station Ventilation

Normal ventilation of MBTA tunnels and stations is partially achieved non-mechanically via the piston effect of the moving trains. A moving train causes an area of high pressure ahead of the train and an area of low pressure behind it. Vent shafts will be located at either end of the Charles/ MGH Blue Line Station platform to allow the normal pressure wave in front of a train to escape to outdoors, and to allow fresh air into the tunnel behind the train. This air exchange serves to control the air quality within the tunnel system as well as to mitigate the pressure wave caused by the moving train before causing objectionable airflows through the station platform, mezzanine and entryways.

Additionally, the station platform will be mechanically ventilated to relieve excess heat buildup from heat sources on the train, such as the braking system and air conditioning units. Warm air will be captured via exhaust ducts located in the ceiling of the station platform and discharged outside. To provide a source of make-up air to replace the exhaust air, a platform supply air system will be provided, either by gravity relief or supply air fans.

Within the proposed station, ancillary spaces, such as toilets and storage rooms, will be provided with exhaust fans as required by code. Spaces containing sensitive equipment, such as communication rooms, electric rooms and automatic fare collection server rooms, will require exhaust with filtered make-up air from outdoors. Make-up air will enter through a vent above grade and be distributed with ductwork to each space as required.

6.1.64 Heating

In general, public spaces such as station platforms and entryways are not heated because they are open to outdoors. However, several ancillary spaces, such as control rooms, electrical rooms and toilet rooms will require heating to prevent equipment failure as well as provide occupant comfort. Electric unit heaters or baseboard heaters will be provided to heat these spaces.

6.1.65 Air Conditioning

Certain ancillary spaces, such as communications rooms and elevator machine rooms, will contain equipment that is sensitive to temperature and humidity and will require air conditioning to prevent equipment failure. Additionally, some spaces, such as customer service rooms, will be provided with air conditioning for the comfort of MBTA employees or patrons.

Electrical

6.1.66 Substation Requirements

Charles/ MGH Station will be provided with a new 480/277V, double-ended substation with drawout air breakers to provide station power. The new substation will be located in a new electrical room below grade, above the new station platform.

6.1.67 Medium Voltage AC Distribution System

The AC System will distribute 13.8 kV medium voltage, via the substation, to the loads associated directly and indirectly with the operation of the system. Included will be tunnel lighting, tunnel ventilation, signal system, and any other loads associated with the operation of the system.

6.1.68 Auxiliary Power System

The Auxiliary Power System will be used to supply power for tunnel ventilation, the tunnel lighting, including light fixtures, signal system, and any other loads associated with the operation of the system.

6.1.69 AC System

The AC Switchgear will be controlled remotely and locally from locations that will be determined later in the design.

6.1.70 Power Distribution

13.8 kV power will be installed underground from an existing MBTA manhole at Longfellow Bridge to serve Charles/ MGH Station. An existing primary feeder 0-3-3 will be interrupted at this manhole. The roadway will be trenched and new duct bank, containing 4" conduits, will be installed from the manhole to a new electric room at Charles/ MGH and routed to new 1200A, 13.8 kV metal-clad switchgear with drawout air breakers. The 13.8 kV metal-clad switchgear will feed power to a 3000A, 480/277V, 3-phase, four wire substation located in the main electric room.

Power within the station will be distributed at 277/480V, 3-phase, four wire with step-down transformers, 480V-120/208V, 3-phase, four wire. Station lighting will be powered at 277V. Tunnel lighting will be powered at 480V, 1-phase. Motors ½ HP and above, including elevators and escalators, will be fed by 480V, 3-phase; motors below ½ HP will be fed by 120V.

Two feeders at 480V, 3-phase power will run from the Charles/ MGH substation to the fan chamber located at the intersection of Charles St. and Sudbury St. The feeders will provide power to the new Motor Control Center located in the fan control room.

6.1.71 Emergency Power

An existing, 300kVA gas engine driven emergency generator currently serves Charles/ MGH. This generator will be replaced with a 500kVA/400kW gas engine driven emergency generator to handle the additional load of the proposed Blue Line Station at Charles/ MGH, including emergency lighting and elevators. Generator transfer switches and panels will be located in a dedicated 2-hour fire rated electric room adjacent to the main electric room.

6.1.72 Lighting

Lighting will be provided to station facilities including platforms, stairs, ramps, pedestrian overpass, elevator areas, entrances and tunnels, utilizing MBTA standard lighting fixtures attaining recommended illuminations levels for all the areas based on IES, APTA and MBTA guidelines.

Emergency lighting will be provided to permit passenger egress from the station and during loss of normal power. Emergency lighting will be provided throughout the platform, stairs, ramps, pedestrian overpass, elevator areas, entranceways and tunnels.

Exit and emergency lights that are sufficient to permit safe exit from platforms in which the public may congregate should be supplied from an emergency power source.

6.1.73 Public Address System

The existing public paging system at Charles/ MGH will be expanded into the proposed Blue Line platform with new speakers to match existing equipment.

6.1.74 LED Signage

LED Signage will be installed at the new Charles/ MGH Station platform as required by MBTA and connect to existing control branch circuits. These signs will provide information to the public as to incoming trains and final station destination.

Plumbing

6.1.75 Station Plumbing

The Charles/ MGH Blue Line Station will be provided with one male and one female ADA compliant toilet facility. A small instantaneous hot water heater will be provided for each toilet facility. The toilet facilities are located below the street sewer, requiring a sanitary pump system to pump waste up and into the city sewer system. The sanitary pumping system will consist of duplex pumps, with each pump sized to handle 100 percent of the design flow. Hose bibs will be provided through out the station platform area to allow for periodical wash down of the platforms.

6.1.76 Tunnel Standpipe System

The tunnel extension to Charles/ MGH under Cambridge Street. will require dry manual standpipes for use by the Boston Fire Department in the event of a train fire or other fire inside the tunnel. Hose outlet connections will be located every 150 feet along the tunnel wall in areas outside of the construction tolerance limit. Multiple standpipe segments will make up coverage for the new tunnel section, with a Fire Department Connection for each section visible on the sidewalk or median.

6.1.77 Station Fire Protection System

The Charles/ MGH Blue Line Station will be provided with Fire Protection systems in accordance with the MBTA Emergency Preparedness Plan, NFPA 130 and the Boston Fire Department. The station platform will have a separate manual dry standpipe system.

In addition to a standpipe system, a sprinkler system will be provided for areas as required by NFPA 130, such as storage areas, the steel truss area above the platforms and other similar areas with combustibles. Fire extinguishers will be provided at each manual dry standpipe connection. Communications rooms will be provided with chemical fire protection systems as necessary.

6.1.78 Fire Alarm System

The existing fire alarm system at Charles/ MGH will be modified and extended as required to serve the proposed Blue Line platform. Fire alarm system devices will be added to the existing fire alarm system such as initiating and alarm devices which will be installed in new rooms and expanded platform areas.

The new initiating devices such as smoke detectors, heat detectors, manual pull stations and sprinklers system will work in unison with existing devices which when activated will signal the area fire alarm control panel into alarm mode which in turn will set off the strobe/horns at the platform area and alert the people that there is a fire and they should head for the nearest exit and evacuate the premises. A signal will also be sent to the fire department which will dispatch fire apparatus to the affected station. Another signal will be sent to the MBTA control station which will alert the MBTA to a problem and potential fire situation at the station.

An exhaust fan control panel will be installed adjacent to the fire alarm control panel with hand-off-auto (HOA) switches for the fire departments control of the exhaust fans for smoke evacuation of the station. The new fire alarm equipment will be of the same manufacturer as the existing equipment.

Station Architecture and Conceptual Design

This section contains general architectural criteria developed the Project. These criteria govern the design of the stations with regard to the discipline of architecture. They address dimensional requirements and constraints, safety criteria, fare collection, accessibility criteria, entrances, stairwells, elevators, escalators, systems requirements, bicycle access and storage, station and way finding signage, lighting, furniture and other station amenities related to station design.

This section is intended to promote uniformity of design and standardization of architectural elements and their future application throughout the system.

6.1.79 Design Considerations

Excellence in contemporary architecture will be emphasized in any new Blue Line Station design. Patron flow of traffic, ADA requirements and safe egress provisions are to be augmented by a spacious station layout, that is enhanced by the use of lighting, vibrant colors and tasteful artwork, to give an exciting experience to the transit user. In keeping with MBTA practice, upscale and ease-of-maintenance finishes such as artistic designed ceramic tile, porcelain enamel panels, stainless steel hardware and slate floors will be used. Every effort is to be made to bring natural day light into the underground spaces. The goal is to rival recent stations on the MBTA system and examples from abroad.

Some design considerations to be considered are as follows:

- Station identity and visibility at a distance needs to be considered.
- Stations need to be sympathetic to the scale and character of the surrounding area.
- Art, signage and lighting are an important aspect to the station design.
- Use of materials that convey an openness and transparency of the transit environment, as well as durability and ease of maintenance should be considered.

6.1.80 List of Applicable Codes, Standards and Guidelines

Codes (most current editions):

- Massachusetts State Building Code 780 CMR, Sixth Edition
- Massachusetts State Elevator Code 524 CMR, 2003
- NFPA 101 Life Safety Code, 1994 (Per 6th edition of CMR 780)
- NFPA 70 National Electrical Codes
- NFPA 130 Fixed Guide way Transit and Passenger Rail Systems
- NFPA 5000 Building Construction and Safety Code
- Massachusetts Architectural Access Board 521 CMR, 2002
- ASME A17.1 Safety Code for Elevators and Escalators, 2000

Standards (most current editions):

- American National Standards Institute (ANSI)
- American Society of Civil Engineers (ASCE)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- Electronic Industries Association (EIA)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)
- Underwriters Laboratories, Inc. (UL)
- U.S. Department of Transportation (DOT/FTA)

Applicable Guidelines (most current editions):

- Accessibility Guidelines for Buildings and Facilities (ADAAG)
- Guide for Emergency Evacuation of Elevators (ASME A17.4)
- American Public Transportation Association (APTA)
- MBTA Guidelines & Standards, 1977
- MBTA Guide to Access, 1990
- APTA Guidelines (American Public Transportation Association), 1981
- ADA Architectural Guidelines (in connection with Uniform Federal Accessibility Standards), 2002
- Transit Capacity and Quality of Service Manual, TCRB Report, 1999
- Pedestrian Planning and Design, Dr. John Fruin, Second Edition 1987
- BCIL Agreement

6.1.81 Qualitative

The design of the station should be an asset to the community, and enhance the area. The design should provide user comfort, and afford access to persons with disabilities. Station entrances provide the link between the station, the city, and the surrounding streets, and their design must reflect the distinct requirements of each. Entrances must provide convenient access for passengers and fit appropriately within the surrounding urban context and community. Station design should also provide pedestrian transfer connections for alternate modes of MBTA transit systems.

6.1.82 Dimensional Requirements

The station geometry should address dimensional criteria with regards to station needs (trains, patrons, entry, etc) so as to accommodate all users and requirements. Design will be based on future LOS analysis. The stations need to be carefully sized and evaluated as to the portion of passengers expected and to the proportions of the site and the surrounding neighborhood.

6.1.83 Safety Criteria

Recommended Practice provides criteria for CCTV camera coverage and fields of view at transit passenger facilities. CCTV cameras are placed in such a manner as to observe and monitor certain locations to aid in maintaining safe and secure transit environments for people, operations and critical infrastructure.

The purpose of safety criteria is to ensure that each transit agency achieves a high level of safety and security for passengers, employees and the public.

Recommended Practice is intended to satisfy the objective to help select placement locations of CCTV cameras at existing and planned passenger facilities; and Identify recommended CCTV camera coverage considerations and fields of view for different types of passenger facilities.

Safety Design Criteria should be used in conjunction with the following:

- CCTV camera original equipment manufacturer (OEM) specifications;
- Individual transit agencies' policies and procedures for placing, maintaining and inspecting CCTV cameras; and
- Other related Security Standards, such as APTA Rail Transit Standard RT-S-SC-012-03, Standard for CCTV Inspection, Testing and Maintenance.

Safety Criteria will reference the FTA Public Transportation System Security and Emergency Preparedness Planning Guide, Chapter 5: http://transit-safety.volpe.dot.gov/Publications/order/singledoc.asp?docid=53 Security Infrastructure APTA SS-SIS-RP-002-08 Final Version 8/26/08

Stations and Transit Centers

Stations and transit centers may require the following coverage and fields of view:

- Entrances/exits:
  - The CCTV cameras should be placed to view pedestrian and vehicular entrances and exits. There may be multiple entrances and exits that may require camera view at each location. Consideration should be given to bidirectional flow.
- General observation:
  - Each station/transit center should have a sufficient number of cameras to provide an overview of the facility. The cameras should avoid obstructions such as structures, shelters, trees and vehicles. When evaluating foliage, consider size of the planting at maturity and seasonal changes. Consideration should be given to ensuring adequate lighting is provided so that cameras provide the best image possible.
- Ticket sales, ticket vending machines and turnstiles/gates, station agent kiosks/booths:
  - The cameras should provide a recognizable image of the person(s) involved in the transaction/interaction.
- Platforms and platform edges:
  - Cameras should provide coverage and field of view of the entire length and width of the platform and platform edge to monitor passenger activity.
- Pedestrian passageways/concourses:
  - Cameras should provide coverage and field of view of the entrances, exits and the entire length of the passageway, including stairways, ramps, elevator lobbies and escalators to monitor passenger activity.
- Access locations to nonpublic areas (ancillary areas):
  - Cameras should provide coverage and field of view to monitor nonpublic entrances/exits, including temporary revenue vehicle storage areas.
- Restricted area entrances:

  - Cameras should provide coverage and field of view to monitor and identify entrances and access points to restricted rights of way (e.g., tunnel portals from station areas or elevated structures).
- Concession areas:
  - Cameras should provide coverage and field of view to monitor concession areas.

6.1.84 Circulation

Stairwells

All stairs must comply with MAAB 521 CMR and MSBC 780 CMR and where stairs are required, there will be a minimum of two stairs per platform. A standard stair unit is planned as 5'-9" wide and will have the following characteristics:

- Risers shall be of uniform height 7 inches maximum, closed and with nosing.
- All treads shall be a uniform width of 11 inches minimum.
- Landings shall comply with MAAB 521 CMR and MSBC 780 CMR.

Elevators

All elevators must comply with MBTA Elevator Design Standard, Rev No.: 02, Rev Date: 06/30/08

Each elevator cab should have a camera mounted in the cab, with the intent to obtain full coverage and field of view of the cab interior and entrance to monitor passenger activity.

Escalators

All escalators must comply with Heavy Duty Transportation System Escalator Design Guidelines Volume 5 - Fixed Structures APTA RT-RP-FS-007-02, Rev Date: *03/10/2006*

6.1.85 Station and Way Finding Signage

Way Finding Design shall be performed in accordance with the current MBTA Way Finding Design standards.

Each station has information panels, which have a map and points of interest and history of the surrounding area. Information panels include the following:

- Panels are similar in design to other panels on the Blue Line.
- There are no obstructions in front of the panels to block the view of persons in wheelchairs, or visually impaired.
- Panels are at a height, which is easily readable from all eye levels.
- Braille is incorporated to accommodate the blind.