A. APPLICANT INFORMATION

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B. EXECUTIVE SUMMARY

This solution is an elegant combination of technology and operations. Trains on overcrowded subway lines are lengthened by 3[1] cars for trains using 75-foot cars and 4 cars on trains that use 60-foot or shorter cars.[2] For example, a 10-car train will have 14 cars and the first 10 cars (cars 1-10) will platform at a station (an "A Station"), and at the next station the last 10 cars (cars 5-14) platform (a "B Station"), at the third station the first 10 cars platform again, and so on through the line. Accordingly, cars 5-10 *always* platform ("Unlimited Cars"), cars 1-4 platform at A Stations ("A Cars") and cars 11-14 platform at B stations only ("B Cars")(A Cars and B Cars are collectively referred to as "Limited Cars"). In effect, the solution allows customers to travel from any station to any station just as they do now, but when they use cars 1-4 or 11-14, they must board a car that platforms at their destination.

Enabling the solution requires modifications to subway cars such that the correct doors, and only the correct doors, open and close at a station. The technology to do so already exists. It is known as selective door opening ("SDO") *and has already been successfully deployed in the London Underground*.[3] A and B stations will generally alternate on each route so that, with a few exceptions, A and B Stations alternate on a line. There are a few exceptions to A and B Stations alternating, but every station is either an A Station or a B Station for *all the lines it serves*.[4]

The SDO Solution will expand system capacity between 40% and 65% on the lines in which it is implemented.[5] The original submission stated the top-end of the increase at 50%, but that amount did not take into account the fact that the SDO solution will be implemented using open-gangway cars which expand capacity an additional 10%. Accordingly, a train that expands from 8-cars to 12-cars increases 50% in terms of cars, but when using open-gangway cars, as is proposed for the L Line, the capacity is increased an additional 10% *layered on top of the 50% increase resulting in an even more dramatic 65% increase in capacity*.[6] Stated another way, open-gangway cars further leverage the SDO solution. The decreased crowding will also speed up service by decreasing dwell time caused by overcrowded cars.

Accordingly, the SDO solution improves the customer experience not in ways that are merely ancillary to the MTA's service, such as customer comfort (which it does as well), *it improves the service itself*. This is the single most important consideration for customers as it does a customer no good to have a car with better lighting if they cannot board a train because it is full.

The cost of the SDO solution is *de minimis* in relation to the benefit of the dramatic expansion in capacity. It would take the construction of approximately 10 subway lines at a cost of at least $200,000,000,000 to achieve even a 40%-50% expansion of capacity, let alone 65%. That is simply not a realistic alternative fiscally, let alone politically or temporally.[7] In contrast, the SDO

[1] Numerals are used instead of text for numbers 1-12 due to the page limit of the Genius Challenge.
[2] Adding 3 75-foot cars increases length 225 feet, whereas adding 4 cars to A Division trains adds only 204 feet.
[3] The purpose in London was to avoid doors opening at selected stations with short platforms.
[4] Designations have been mapped out assuming full implementation of SDO on *every* line (which is not proposed, but is a conservative assumption for the purpose of testing SDO), and *there are never more than 2 A Stations or 2 B Stations in a row on any line*. While "A" and "B" are used herein, obviously different designations could be used.
[5] Several lines, at least the 1, C, G, J, M & Z, are not at capacity and would not need to use SDO.
[6] The math is 8x1.5=12, 12x1.1=3.2 and 13.2/8=1.65. For 10-car trains expanding to 14 cars, the increase is 54%,.
[7] Unlike constructing new lines, SDO does not require digging up neighborhoods, disturbing residences, disrupting businesses and congesting street traffic and can be implemented nearly system-wide in approximately 10 years with the first line implemented in just 4 years.

solution costs approximately $11,800,000,000 as recommended, less than the Second Avenue Subway will cost.[8] Furthermore, in contrast to One Person Train Operation ("OPTO"), SDO increases the efficiency of operators and conductors 40% to 65%, *without costing a single job*.[9] Instead of 2 workers for every 8 or 10 cars, there will be 2 workers for every 12 or 14 cars increasing efficiency 40% to 65%.

In terms of implementability, the London Underground deployment conclusively demonstrates the viability of SDO. In fact, there are at least 3 different technologies that can be used for SDO, which can be used redundantly as an extra measure of safety.[10] Indeed, SDO has matured to the point where there are industry standards for it in the U.K. In fact, most of the implementation issues are traditional rail issues.

Moreover, implementation of the SDO solution is also flexible and scalable. First, although this application recommends nearly system-wide implementation, the MTA can choose which lines to expand under SDO. Second, the MTA can lengthen trains by less than 3 or 4 cars when appropriate. These tools can also be used in *reverse* if ridership decreases.

Finally, in essence, the SDO solution melds, for the first time, several proven technologies and operational concepts by using combining the SDO technology developed in Europe with open-gangway cars and using the skip-stop service concept presently utilized on the J and Z lines to creatively, quickly and economically increase capacity and reduce dwell times.

There is simply no other known idea that can increase capacity this dramatically, this fast, this economically in such a targeted way and with so little disruption and construction.

C. TECHNICAL OVERVIEW

1. Technical Components and Specifications

a. Technical Components. There are 3 methods to implement SDO: (1) using readers on cars and beacons/tags on platforms; (2) Global Navigation Satellite Systems ("GNSS"); and (3) distance-based calculation systems.

1) *Readers and Beacons/Tags*. Under this method, deployed in the London Underground, passive beacons or tags are mounted at platforms that store information relevant to the platforms. The tags do not require power or batteries. Powered readers are installed on cars to read the data on the platform tag.[11] The system can work either as train-based for modern computerized control trains or as car-based for trains without computerized control, or for trains in which computerized controls are fully-utilized for other purposes.

i. *Train-Based*. Each operator's cab has a reader to read tags at station platforms. The tag identifies the station to the train and the correct doors are enabled as programmed for that station either in: (a) the train's existing computer; or (b) a programmable logic controller ("PLC"). Train-based controls can also enable particular doors within a car.

[8] Options to refurbish cars and/or lengthen key platforms would increase the cost approximately $5,000,000,000.
[9] There is a modest ancillary increase in maintenance jobs, simply because more cars are needed for SDO.
[10] Safety is also improved because SDO inherently ensures that doors on the correct side of the train are operated.
[11] Beacons are placed between the tracks while tags are smaller and placed on platforms. Using tags permits the system to also provide correct side door enabling/opening ("CSDE"), at no additional cost and also avoids the tags getting covered with snow. Accordingly, tags are recommended. See § I of the Supplemental Materials for a schematic of the reader and tag system and links that describe the London Underground project by Sella Controls.

ii. *Vehicle-Based*. Each car has a reader installed and a tag is installed at the start of each station platform. As each car passes by the tag, its doors are enabled through an interface between the reader and the door control circuits.[12]

2) *GNSS*. This system determines a train's location with GPS and similar guidance systems, but is not precise enough to identify specific platforms when there are multiple platforms, for which tags or other methods are used. GNSS is only usable above-ground.

3) *Distance-Based*. This system calibrates the distance travelled by using axle rotations after calibrating the rotations with the distance between known locations, including with GNSS.[13]

As space is limited, this application is based on the Sella Controls reader and beacon/tag technology successfully deployed in the London Underground, but it is important to note that the 3 methods are *not* mutually exclusive, but complimentary, and combining them adds an extra measure of safety and redundancy and all methods should be considered.

b. Specifications. The general specifications[14] for the train-based system deployed on the London Underground in the UHF frequency band are:

1) *Passive Tag*. The passive tag is a beam powered Radio Frequency ID ("RFID") device, requiring no power or batteries. It contains a circuit board comprising an antenna and RFID device that is energized by the RF field transmitted by a train-mounted antenna. Tags are pre-programmed with data needed for all door opening patterns at all stopping positions. It is constructed from flame-retardant polymer with an aluminum base and factory-sealed to IP 67.

2) *Reader*. The reader is an RFID interrogation device. For train-based systems, 1 is mounted to the underside of each driving car (i.e., 2 per train). Each reader connects to 2 antennas, 1 on each side of the train, and knows which of the 2 antennas has detected a tag. The readers energize and read tags from approximately 1 meter and operate continuously, reading tags in range several times per second. The tags are used while the cars are moving slowly near a platform, but they can be read at speed and have been successfully tested at speeds up to 125 mph.[15] The reader connects to a Control Unit, based on a dual-processor PLC certified to Safety Integrity Level 3 for both its internal hardware and as a "software programmable" platform (i.e., a fail-safe architecture).[16]

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[12] Having only a single reader at the rear of the platform works at A Stations when only the rear doors remain closed. For B Stations, for the 4 cars in front that do not platform, a second tag is needed at the front of the platform to disable those doors. Alternatively, the distance traveled from the rear tag can be used to determine if the forward cars have passed the platform. As a redundant safety measure, a second tag should be placed at the front of all platforms, even at A stations so that doors in the front of the train do not open if a train overruns a platform.

[13] This method is used by Petards Group PLC ("Petards"). Petards obtained a £4.3 million contract to design, develop and supply Stadler Bussnang AG ("Stadler") with CCTV and SDO systems for Stadler's FLIRT UK trains. The system works on subway systems as well. The £4.3 million contract covers 378 new cars, and 58 trains (20 of 12-car length, 24 of 4-car length and 14 of 3-car length), as well as 18 stations for the 2 lines on the East Anglia franchise. Petards has contracted with 3 fleets in the UK for SDO. Interestingly, Petards uses cameras over each doorway that feed a monitor to the door operator's cab, so ingress/egress progress can be seen clearly.

[14] See § I of the Supplemental Materials for links to detailed specification sheets.

[15] The system can be used for any geographically-triggered function.

[16] In the event of reader failure, the door operator uses a manual override.

2. Interface with the MTA's Existing System

The car-based solution definitely interfaces with the MTA's existing system as it works without a train computer. The interface to the door control circuits is done via outputs in reader.

The SDO reader/tag system successfully interfaces with several different computer controls from different manufacturers, and it is believed it can do so with the MTA's new technology trains ("NTT"). If it does not, at a minimum, a car-based system can be used, if not a safety PLC.[17]

3. Proprietary Technology & Interoperability

The solution uses proprietary technology, but multiple vendors offer multiple technologies. The 3 systems are not mutually exclusive, but rather 1 vendor has stated that all 3 technologies can be used together to have redundancy and increase safety and reliability.

4. Key Assumptions Requiring Validation for Viability

The key assumptions requiring validation are not technical and do not concern the ability to enable SDO on the MTA's trains, which the London Underground and other deployments in the U.K. demonstrate can in fact be done, but rather involve secondary issues addressed in detail at Section D(4) *infra* regarding implementation and operation.

5. The Key Benefits of the SDO Solution

The benefits of the solution are nothing short of transformative.

40%-65% Capacity Increase. If fully implemented, the SDO Solution will result in the greatest expansion in capacity of subway service since the construction of the IND. A 40% to 50% increase in capacity would require constructing approximately 10 additional subway lines. Unlike Computerized Based Train Control ("CBTC") which has limitations on increasing capacity due to certain bottlenecks such as the sharing of tracks, stations and platforms. The SDO solution uses the *existing* train schedule and therefore increases capacity universally across all lines in which it is implemented, which will be most of them.

Cost. The $11,800,000,000 cost of the solution, is a bargain and virtually inconsequential in relation to the extraordinary benefit. The foregoing is demonstrated by comparing the cost of the SDO solution to the cost of the Second Avenue Subway ("SAS"). Phase 1 of the SAS cost approximately $4.5 billion, adding *just 3 stations*, Phase 2 is projected to cost $6 billion and will also add 3 stations, Phases 3 and 4 have unknown costs, but it is fair to project that the SAS will cost approximately $20 to $25 billion. Accordingly, expanding subway service 40% to 50% by building additional subway lines requires adding approximately 10 lines to the existing approximately 20 lines, which would prohibitively cost $200 billion to $250 billion.

No Disruption. While the SDO solution does not expand the geographic reach of the system the way additional subway lines would, it expands capacity without digging up neighborhoods, disturbing residences, disrupting businesses and congesting street traffic. Moreover, the crowding in the system constitutes *a demonstrated demand for additional service* whereas building additional lines can involve a risk of inadequate demand once a line is built.

[17] See § I of the Supplemental Materials, "Technology" link at "Vehicle Based ASDO Solution" and "Train Based ASDO and CSDE Solutions."

Speed. Even if the political will and money existed to add subway lines, which it does not, doing so would take decades and perhaps more than a century. The SDO solution can be implemented starting in approximately 4 years on the 7 and L lines and implemented system-wide as fast as the additional rolling stock needed to lengthen the trains can be procured, far faster than CBTC. Conversely, while speed is the essence of the Genius Challenge, the SDO solution can be implemented more slowly than set forth herein should it be desirable to do so.

Scalability. The SDO solution is scalable 2 ways. First the MTA can choose how many cars to add to trains within each line (2, 3 or 4). Second, it can be rolled out on a line-by-line basis, permitting it to be implemented where it is needed most. While this application seeks implementation nearly system-wide, a more limited approach is possible implementing only on selected lines, perhaps only using 100% open-gangway cars on those lines. After implementation, if demand changes, on any line, service can be adjusted, including downward.

Dwell Time. Dwell time will decrease for 3 reasons. First, the reduced crowding on the cars will make ingress and egress faster for customers as it simply is easier to move in less crowded space. Second, SDO motivates customers to use the ends of platforms because customers using Limited Cars will use the front or rear of the platforms, reducing crowding at the center of platforms. Third, the SDO solution inherently spreads out customers using All-Station cars along station platforms. For example, a customer embarking at an A Station in the middle of the platform, will be at the *front* of the platform when disembarking at a B Station because of the different position of the train relative to the platform.

Comfort. All cars will be dramatically less crowded and more seats will be available overall. Also, customers on Limited Cars will only be jostled by other customers embarking or disembarking at half of the stops instead of at every stop.

Labor. The SDO solution costs *not a single* job, but increases the efficiency of operators and conductors by 40% because instead of having 2 workers for every 10 cars, there will be 2 workers for every 14 cars. In other words, it obtains 40% to 65% of the efficiency sought by the OPTO idea, but without any harm to labor. To the contrary, at least 3 of the ideas below regarding storage of cars overnight, § D(4)(e)(4), (5) & (7), as well as additional jobs for maintaining the expanded fleet, add good, living-wage, permanent jobs, albeit in an admittedly modest amount. In the short term, SDO adds construction jobs in New York and adds manufacturing jobs, possibly in New York, to the extent additional rolling stock is procured.

Again, there is simply no other known idea that can increase capacity this dramatically, this fast, this economically in such a targeted way and with so little disruption and construction.

6. Supplemental Material § I

The Evaluation Committee and Judges are respectfully referred to Supplemental Material § I for a schematic of the train-based reader/tag SDO system, links describing SDO and its deployment in the London Underground and links to specification sheets for SDO equipment.

D. IMPLEMENTATION DETAIL

1. Phase of Development and Deployment

The system is fully-deployed and in commercial use. There is no need for research and development.

2. City and Country Where the Solution is Developed and Deployed and the Results

The SDO solution has been successfully deployed on multiple lines in the London Underground, and on commuter rail lines within the U.K. for the related purpose of accommodating inconsistent platform lengths. Indeed, the technology has matured to the point that rail industry standards have been implemented in the U.K. *Rail Industry Standard RIS-2747-RST*, §§ 4.1-6.6, Functioning and Control of Exterior Doors on Passenger Vehicles, March 2017, which expressly states at §G 4.2.2 "[t]hese options are proven systems that provide the information about which doors are to be enabled/released to the member of staff/system responsible for controlling the door."[18] The reliability of the technology is unquestionably demonstrated.

3. How the Solution Addresses Regulatory Requirements and Industry Standards

The underlying structure of the SDO solution is such that the service will be largely the same as the existing service except that trains will be longer and not all cars will platform at every station so as to expand capacity virtually system-wide (except for the 1, C, G, J, M, S & Z lines).[19] Accordingly, in respect of revenue service, the most significant change that may implicate regulatory and/or industry standards is that SDO will cause trains to be as much as 480 feet closer together when one train is stopped at an A Station and the train behind it is stopped at a B Station.[20] This could be an issue where stations are close together. Still, as the trains proceed 1 station forward the front train will be at a B Station and the rear train will be at an A Station *re-establishing the distance that exists between trains now*. In any event, whether or not the described increased proximity of trains implicates regulatory requirements, the issue should be mitigated through signaling, CBTC and/or speed limits as required.

In respect of industry standards, the aforementioned U.K. railway standards address the use of SDO when passengers cannot travel between cars. As the issues overlap with the operational issues below, how the SDO solution relates to the standard is addressed *infra* at § D(4)(f).

4. Implementing and Operating SDO, Including Mitigation of Key Risks[21]

Implementation and operation of the SDO solution entails more than installing SDO capability itself. The ancillary issues include: (a) car signage; (b) station signage, platform signage and map changes; (c) installing platform cameras and monitors for door operators; (d) acquiring additional rolling stock; (e) storage of trains during off-peak service hours; (f) scalability of train lengths; (g) signaling; (h) lengthening key platforms (optional); and (i) additional electric power.

a. Car Signage and Car Announcements. It will help customers if the signage capability on cars is modified so it can show whether a car is a Limited Car and/or an A Car or B Car specifically. Since trains reverse directions, the signage needs to change from A to B or B to A when a car reverses direction.[22] This includes signage on the car's interior and exterior that presently designates the train's service line. Similarly, cars with ticker signage near the ceiling should display whether the next station is an A or B Stations and which cars will (or will not) platform. Automated announcements can be made to the same effect. Conversely, cars that

[18] Available at: https://www.rssb.co.uk/rgs/standards/RIS-2747-RST%20Iss%201.pdf.
[19] A Title VI assessment may be required. If so, the MTA will apply its System-wide Service Standards.
[20] In the limited cases in which there are 2 A or 2 B Stations in a row, trains will be about 240 feet closer together.
[21] While this section addresses the risks required by § D(4), it also includes independent ideas for improved service.
[22] In the absence of electronic signage that can make the foregoing change, signs can state "Limited Platform Car."

always platform should be designated "All Platforms" or "Unlimited." Also, if a car will always be used as a Limited or Unlimited Car, its flooring could state its type and/or be color coded.[23]

b. Station Signage, Platform Signage, Maps and Public Information. Presently, when customers board a train, they can randomly select any car (that is not full) and know it will platform at their destination.[24] With the SDO solution, the chance of randomly boarding a car that platforms at their destination is 80%.[25] While the most crucial customers are commuters who will not regularly need signage, they will not be the only users. Accordingly, station and platform signage should enable a first-time customer, or an existing customer using the system for non-routine transport, to determine which car to board (Limited or Unlimited) with as little effort as possible. Station and platform signage is the key to doing so. Fundamentally, a customer needs to know 3 things: (1) the class, A or B, of the boarding station; (2) the class of the destination station;[26] and (3) the platform areas for Limited Cars and Unlimited Cars.

1) *The Class of the Boarding Station*. All signs at entrances to stations should state whether a station is an A Station or B station and possibly at turnstiles as well. All A Stations should be color-coded as maroon (the color of the front maroon trim and stripe on R142A cab cars)[27] and B Stations as blue and the name of the station be written in maroon or blue accordingly, and even rotating turnstile bars can be color-coded. The light balls at station entrances should have a maroon A or blue B on the ball. In addition, the subway map should be marked not only to state whether a station is an A Station or a B Station but also the names of the stations should be printed in maroon or blue to further reinforce the color-scheme cues.[28] Finally, third-parties will likely develop smart-phone applications to assist customers in navigating the system to use the correct cars, and the MTA should facilitate this. The subway map and smartphone applications will help customers make determinations before they even arrive at a station.

2) *The Class of the Destination Station*. Signs should be posted showing the *remaining* stations on the line, similar to the line maps shown on subway cars and timetables. The signs would: (a) expressly state whether a remaining station is an A or B Stations; (b) print the names of A Stations in maroon and B Stations in blue;[29] and (c) print stations of the same class as the present station in boldface and stations of the opposite class in ordinary typeface (for example, at an A Station, all A Stations listed would be in boldface and B Stations would be in regular typeface). These signs can be posted: (a) everywhere maps of the subway system, the station and/or surrounding neighborhood are already posted; (b) next to all station-agent booths; (c) next to MetroCard machines; (d) in regular intervals on the platforms; and (e) where there are structural columns on the platform on *each* column in the area of the platform

[23] More information is needed from the MTA on this sub-idea, specifically how often trains are reconfigured and how hard it would be to require cars to always be in a Limited or Unlimited position in a train.
[24] The only known present exception is 145th Street on the 3 Line which has a platform 6 cars long.
[25] There is a 60% chance customers will board an Unlimited Car and a 40% chance they will board a Limited Car. There is a 50%/50% chance that the Limited Car will platform at destination. So, 80% = 60% + (50% x 40%).
[26] In the case of a transfer, the customer needs to know the class of the transfer station. Once at the transfer station, the customer only needs to learn the destination station's class, as they will know the class of the transfer station.
[27] Viewable here: http://talk.nycsubway.org/perl/read?subtalk=474973
[28] Again, every station will be all A or all B for *all* lines. Achieving this sometimes means there be 2 A or 2 B Stations in a row (for example, when lines merge), but there are *never* more than 2 A or 2 B stations in a row.
[29] Alternatively, stations of the opposite class could be written in green, cuing customers to use Unlimited Cars.

used for Limited Cars, but in any event at least 1 sign per subway car length. The subway map and smartphone applications will help customers make determinations as well.

3) *Platform Areas for Limited Cars and Unlimited Cars*. The yellow tactile edging currently installed on platforms should be replaced and color-coded. At an A Station, the edging would be maroon where the first 4 cars platform, and at a B Station the edging would be blue where the back 4 cars platform, at all stations the portion of the platform for Unlimited Cars would be green.[30] "A Car", "B Car" and "Unlimited Car" should be included with the edging similar to the "Step Aside" text sometimes used.[31] Structural columns located on the platform could also state whether the area of the platform is A, B or Unlimited, with the text, or its background, in maroon, blue or green. The signs above the platforms that currently state the hours and lines of service could further state the location of A, B and Unlimited Cars and the sign's background color should be maroon, blue or green depending on whether the sign itself is in an A, B or Unlimited boarding area as a further cue. Customers would then know in advance that they are in position to board an A Car (maroon), B Car (blue) or Unlimited Car (green), which the markings on the car will confirm when the train arrives. Signage should also be placed in appropriate locations directing customers to limited and unlimited boarding areas.

4) *First Implementation*. When the SDO solution is first implemented, particularly on the first line in which it is ever implemented, the public will need to be educated about the solution and how it works. The MTA will need to engage the media both generally and in the local areas in which the service begins. Information also needs to be posted on the MTA's website and literature and temporary signs need to be posted and available at all stations on the line before the solution is implemented, with the intensity increasing as the start date approaches. In the week before the service starts, the MTA should have staff on hand at the stations in which the heaviest boarding occurs so customers can ask questions and obtain any information they need. Finally, on the day of implementation and the following days, MTA personnel should be on the platforms to assist customers as needed. Again, the first line implemented will be the biggest lift, as it will both educate customers about the solution itself and the particulars of the implementation on the line. Each later line should be easier than the prior one as customers use the system. The MTA should implement the solution on the 7 Train first because: (1) it overlaps with no other lines, simplifying implementation; and (2) it will have CBTC and therefore not need signal changes. The L train will be second, for the same reasons.

c. Platform Cameras and Monitors.[32] Presently, conductors are in the middle of the train and the middle of the platform with the most distant car doors 5 car-lengths away. Under the SDO solution, for retrofit trains, the conductor will still be in the middle of the train, but will be 7 cars away from the front of the platform at A Stations, and 7 cars away from the back of the platform at B Stations. For new, open-gangway trains there will only be cabs at the front and rear of the train. (Q&A 31.)[33] This means that the doors will be opened and closed from the front of

[30] Obviously different colors could be used, I have tried to pick colors significantly different than the gray tile, but that aesthetically coordinate with the system. A yellow stripe can be included if needed for safety.
[31] For platforms that serve both SDO and Non-SDO trains, such as platforms that serve both the A and C Trains, it might also be worth stating the applicable train line in the edging to avoid confusion for non-SDO trains. That said, there is no "wrong car" on non-SDO trains so if customers using a non-SDO line mistakenly think a platform area is limited, the worst thing that happens is they use center cars, so it may not be necessary to add the line information.
[32] Alternatively, cameras could be installed above car doors as Petards does, which might be more economical.
[33] "Q&A #" refers to the Phase 2 Technical Questions and Answers.

the train and platform for A Stations, and the rear of the train and platform for B Stations.[34] Accordingly, platform cameras need to be installed for, at least, the 5 cars most distant from the conductor. It is recommended that cameras be installed for the entire length of the platform to reduce dwell time and to prepare for the arrival of open-gangway cars.

d. Additional Rolling Stock. The MTA has effectively no unused rolling stock available to expand train lengths.[35] (Q&As 56 & 59.) Accordingly, implementing SDO requires acquiring more cars.[36] (Q&A 131.) For the A Division, the need will be met by reconfiguring existing trains, by breaking up existing trains and adding their cars to other trains to lengthen them by 4 cars.[37] Because that reconfiguration will reduce the number of trains on each line, new (14-car) trains must be acquired so each line has at least the same number of trains it has now, including an extra 20% to maintain the ratio of trains that are in and out of service.

For the B Division, there is an additional step because it uses 75-foot car trains and 60-foot car trains, but only 60-foot cars will be procured. Accordingly, the D, F and N/W lines will transfer their 75-foot cars to the A, B and R lines which, other than the G Line and shuttle services, will be the only lines using 75-foot cars going forward.[38] The transfers will be as follows:

B receives 24 75-foot cars from the N/W B receives 66 75-foot cars from D service cars	R receives 33 cars from D *spare* cars[39] R receives 77 cars from D service cars
A receives 56 cars from the F, 8 of which replace its R32 train, so net gain is 48 75-foot cars A receives 88 75-foot cars from D service cars	

The D, F and N/W lines will all receive new 60-foot cars to replace the 75-foot cars that they transfer, and the D Line will be 100% open-gangway.

The following chart shows the cars needed to be acquired and transferred to implement SDO in the order in which the lines will be implemented on the relevant lines:[40]

[34] Doors may be operated from the rear at A Stations if monitors are installed aft of the station. Monitors at outdoor stations will require a protective shelter. Experience from cameras used on the L Line OPTO project may be helpful.
[35] Approximately 20% of cars are not in service at any one time because there are 3,523 B Division Cars and 2,895 A Division cars, for a total of 6,418 cars, while 2,942 B Division cars and 2,396 A Division cars are in service, for a total of 5,338 cars. 6,418/5,398=1.202, or 20%. (Q&A A and B Division Car Assignment Attachments at Shop Assignments.) However, those cars, with insignificant exceptions, are not available for service. (Q&A 56, 59.)
[36] The new cars are a significant SDO expense, but the risk of acquiring the cars is slight because over 50% of the cars will be acquired anyway. Moreover, even if SDO is completely abandoned *after* the cars are acquired, the money will not be wasted. First, open-gangway cars expand capacity 10% in and of themselves. Second, the MTA could retire 985 R62 and R62A cars from the A Division, and approximately 1,050 R46 and R68 75-foot cars from the B Division, to modernize the fleet. Third, the new cars could be used for more frequent service as more trains are needed when signaling is converted to CBTC and for additional Second Avenue Subway service. In other words, a combination of modernizing the fleet and future service expansions fully mitigates the risk of acquiring the cars.
[37] An underlying assumption is that cab cars can be used as regular cars, or be modified to be used as regular cars.
[38] Even these lines will eventually phase out 75-foot cars. (Q&A 131.)
[39] The remaining 13 75-foot spare cars attributable to the D can be reserved or retired.
[40] 1, C, G, J, M, S & Z trains will not be expanded unless and until additional capacity is required. 75-foot car data is red, the D, F and N/W now using 75-foot cars will use 60-foot cars so data to the right of column F is black. The rows that change from red to black have a disproportionately high number of cars the "Cars for SDO" column because in addition to lengthening the train, the *base* train itself is being replaced with 60-foot cars.

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
Implement Sequence and Date	Line	60' or 75'	No. of Trains	Cars/ Train	Current No. of Cars	Future Cars/ Train	Cars for SDO	Spare Cars @ 20%	Total Need	F, G, N/W Txfrs	D Txfrs	Net Car Need
1 1/2022	7	60'	36	11	396	15	144	29	173			173
2 1/2024	3	60'	25	10	250	14	100	19	119			119
3 9/2024	2	60'	34	10	340	14	136	32	168			168
4 6/2025	5	60'	34	10	340	14	136	32	168			168
5 1/2026	4	60'	35	10	350	14	140	28	168			168
6 10/2026	6	60'	39	10	390	14	156	33	189			189
A Total												**985**
1 7/2022	L	60'	24	8	192	12	96	18	114			114
2 1/2024	B	75'	25	8	200	11	75	15	90	-24	-66	0
3 9/2024	R	75'	30	8	240	11	90	20	110		-110	0
4 6/2025	A	75'	38	8	304	11	114	22	136	-48	-88	0
5 3/2026	D	75'	29	8	232	14	406	84	490			490
6 9/2026	Q	60'	21	10	210	14	84	21	105			105
7 3/2027	N W	60'	30	10	300	14	120	27	147			147
N/A	N W	75'	3	8	24	14	42	7	49			49
8 9/2027	E	60'	26	10	260	14	104	22	126			126
9 6/2028	F	60'	37	10	440	14	148	27	175			175
N/A	F	75'	7	8	56	14	98	21	119			119
B Total												**1,325**

Some amounts in the 20% column are adjusted slightly (up or down) so only whole trains or half trains are ordered. Also, similarly to the D Line, the L line will eventually become 100% open-gangway. This will be achieved by swapping the L Line's non-open-gangway cars with trains that would have gone to the Q and N/W. This is done because the L Line is the only SDO line that has 8 60-foot cars, and therefore has the shortest trains. The other reason concerns the expanding 8-car trains to 12 cars without over-crowding Unlimited Cars. See *infra* at § D(4)(f).[41]

The present fleet will increase by 985 A Division and 1,325 B Division cars, for a total increase of 2,310 cars. To achieve the increase: (a) after the R-32 and R-42 cars are retired, no further cars will be retired as more cars are acquired; and (b) additional 60-foot cars will be ordered in both divisions. Under the present R179 and R211 contracts the MTA will receive 1,400 cars, 300 under R179 and 1,100 under R211 (not including the 75 Staten Island Railway cars). After retiring the 154 R-32 and 40 R-42 cars (194 cars total), the fleet will therefore already increase by 1,206 B Division cars (1,400-194=1,206). Accordingly, the MTA will need to order 985 more A Division cars and 119 more B Division cars (1,325-1,206=119), for a total of 1,104 more cars.

[41] Prior to becoming 100% open-gangway in or about late 2026, the L Line may "only" have 11-car trains.

All future cars, including A Division cars and all R211 B Division cars, should be open-gangway only, even if deliveries take longer because open-gangway cars: (a) further expand train capacity ***on top of the 40% increase achieved by train lengthening***, so the total result is a ***54% increase*** over present service for 10-car trains expanding to 14 cars, a ***51.25% increase*** for 8-car trains expanding to 11 cars, and a whopping ***65% increase*** for 8-car trains expanding to 12-cars, like the L Train;[42] (b) allow customers to move within a train to balance capacity; (c) allow customers to move within the train for their own comfort; and (d) permit customers to move to another car if they board a Limited Car but need an Unlimited Car.

Finally, like the L and D lines, the MTA should consider consolidating open-gangway cars onto particular lines so that all cars on that line are 100% open-gangway. In the A Division, there are enough cars to make the 3 Line and 1 other line 100% open-gangway. For the B Division, in addition to the L and D, there are enough cars, 529, for one of the E, Q or N/W lines.[43]

e. Train Storage and Maintenance Sheds. More cars require more storage when they are not in service, particularly overnight when the most cars are not in service. Also, since trains will be longer, some storage tracks need lengthening. Maintenance sheds will also need enlarging to avoid decoupling them for service.[44] There are several options to meet these needs, including:[45]

1) *Reconfigurations*. At least some yards need to be reconfigured so that their tracks can hold the longer trains and maintenance sheds enlarged;

2) *Storage on Tracks Not Needed for Off-Peak Revenue Service*. There are tracks, such as the express track for the 7 train, that are not needed for service at off-peak times. At least a portion of those tracks can be used to store cars mid-day and overnight. These tracks are ideal because they position the trains where they are needed when they resume revenue service;

3) *Storage on Tracks Not Used for Any Revenue Service*. According to publicly-available information, there are numerous tracks not used for revenue service at all, including center tracks on numerous A Division lines in the Bronx and the end of the N/W Line in Queens,[46] "express" tracks at the end of the F line in Queens and the end of the N and D Lines in South Brooklyn. These tracks might be used for off-peak storage. Similarly, track could be constructed and used for storage in places in which there is track bed, but no track;

4) *Storage Using End-of-Line Shuttle Service*. The MTA stores trains overnight on mainline track "in selected instance[s]." (Q&A 144.) Accordingly, for overnight storage, after at least midnight, but as early as 9 PM, shut down service at the last several stations on the *arrival track only* at the end of a line and use it for storage while using the departure track to shuttle customers to and from the end of the line to the 4th or 5th station on the line. For example, for A trains to Inwood, the trains would terminate at 175th Street, where a 2 or 4-car shuttle train across the platform would take customers to Inwood and the other 3 stations *on the departure*

[42] For example, for 10-car trains the math is 14/10=1.4, or 40%, for the additional cars, and *then* a 10% increase by using open-gangway cars: 1.4 x 1.1 = 1.54, or 54%. Not all cars will be open-gangway as existing cars will still be used. Accordingly, the *weighted* average increase is approximately 44% for 10-car trains expanding to 14-cars.
[43] At least one of the lines should serve Queens as the D and L lines serve the Bronx, Brooklyn and Manhattan.
[44] If sheds cannot be expanded quickly enough, decoupling can be utilized in the interim. In addition, decoupling can be used to mitigate the risk of the cost of expanding maintenance sheds.
[45] It is assumed that all planned yard expansions, including building a yard at Sunnyside, are utilized by other needs.
[46] I hesitate to recommend using the end of the N/W Line since it should be extended to La Guardia airport and the center track used for express service to and from the airport on the W line.

track only, then reverse and head back to 175th Street, again on the departure track, picking up customers who will walk across the platform at 175th Street for the next outbound train.[47]

Storage uses arrival tracks on this side up to, but *not* including, 175 Street

```
============================/===(passing loop)====/=========================
Inwood   207 St Yd Access   Dykman   X   190 St   X   181 St   175 Street   X
=================================================================================
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Shuttle uses departure tracks on this side ("X" denotes switches)

The arrival/storage track can store approximately 10 extended-length A trains from Inwood to 175th Street: (a) taking pressure off the 207th Street yard (which is still accessible via the shuttle track); and (b) positioning the trains perfectly for their runs in the morning with no dead-head time. This same technique could be used at the end of other lines, including the other end of the A line between Rockaway Park Beach-116 Street and Broad Channel and the 5 Line from Dyre Avenue to East 180th Street, which *already* use shuttles at night. The key is having a station a few stations from the end of the line with a center platform, or at least a mezzanine or cross-over passage to allow customers to stay on the fare side to transfer to the shuttle. It is also best if the transfer station is underground in terms of passenger comfort;[48]

5) *Add Trains to Overnight Service*. Trains could be added on some lines to reduce overnight storage and increase the level of overnight service, for example, increasing service on the E line, including express service, which would also benefit JFK Air Train service;

6) *Storage Using Rehabilitating Abandoned Tunnels and Track.* Abandoned parts of the system might, depending on their condition, be worthy of refurbishment to use as storage. For example, the Atlantic Avenue tunnel could store 4 to 6 trains if reconstructed;

7) *Reconstructing the 3.5-mile Rockaway Beach Branch Line*. There is controversy over what to do with this asset. Daytime revenue service and nighttime storage is a compromise by using the tracks only to lay up trains from 9 PM to 6 AM to eliminate noise issues. There is room for at least 2-track service on the branch and perhaps room for more. If there is "only" space for 2 tracks, approximately 44 extended-length trains could be stored, 66 if room for 3 tracks and 88 if room for 4 tracks. The branch is near the ends of ***numerous*** B Division Lines;

8) *The L Train*. The Canarsie yard can be slightly enlarged and reconfigured on its current side of the Canarsie Station to allow the existing tracks to be extended and other tracks to be reconfigured. The free bus transfer on the yard side of the station is largely irrelevant with the availability of MetroCard transfers or the upcoming electronic system, but in any event a farecard or even a paper transfer solution could be implemented as a substitute for the fare-side bus boarding. Alternatively, the free bus interchange could be moved to the large parking lot on the other side of the station. Similarly, if reconfiguration on the existing side is insufficient,

[47] After midnight trains have 20-minute headways on the A train. The service schedule shows it takes 8 minutes for a train to travel from Inwood to 168th Street. I am assuming that it will take 6 minutes to travel between Inwood and 175th Street. This means that a shuttle will use 12 minutes to travel roundtrip, and have 4 minutes at either end to change direction. In short, the shuttle service would run the way the Franklin Avenue shuttle runs overnight. Between 9 PM and midnight, A train headways are shorter and 2 shuttle trains are needed so that the 175th Street transfer for customers is seamless. This would require *not* storing a train mid-point, perhaps at the 190th Street station, so that track could be used as a passing loop. This might require installing switches and signaling equipment if none exists now. Signaling might also have to be changed to allow bi-directional service on the shuttle tracks.

[48] I believe this idea is worthy of independent consideration even if the SDO solution is not adopted.

the yard could be expanded to the other side of the station in lieu of the parking lot, or perhaps it would be economical to construct an elevated parking lot and use the ground level for more storage tracks, providing the trains protection from the elements. Also, a study from 2008 stated "between Broadway Junction and Sutter Avenue, . . . large sections of elevated deck remain that currently serve no active purpose. These sections should be: a) reused for car storage . . . ." Broadway Junction Transp. Study: NYC Dep't of City Planning, Nov. 2008.

9) *Constructing elevated yards over existing yards*. This is an idea of second-to-last resort due to the expense of constructing the elevated yard, expense of maintaining it and the visual appearance, still it avoids the cost and dislocation of acquiring new property and perhaps could be done in a way that is unobtrusive and/or allows for development above the yard; and

10) *Creating new yards*. As a last resort, additional property could be acquired by purchase and/or eminent domain to create new yards, if the MTA does not already own adjacent land. As the yards are in the far reaches of the City, the value of adjacent land will not be high.

f. Train Length Scalability and Balancing Capacity. Statistically, 50% of all customers will disembark at the opposite class station of which they embarked (25% A to B and 25% B to A). The remaining 50% will embark and disembark at the same class station (25% A to A and 25% B to B). Accordingly, on existing trains, future Unlimited Car customers effectively use 5 cars on a 10-car train, while future A and B Car customers effectively use 2.5 cars each. When expanding a 10-car train to 14 cars, there will be 6 Unlimited Cars representing 60% of the length of the old 10-car train, 4 A Cars representing 40% of the old train and 4 B Cars also representing 40% of the old train. Accordingly, the 50% of the customers from the old 10-car train that need to use Unlimited Cars will now have 6 cars available for service instead of 5, a 20% increase (6 cars/5 cars=1.2). The 25% of customers from the old 10-car train that need to use A Cars will now have 4 cars available for service instead of 2.5, a 60% increase (4 cars/2.5 cars =1.6). Accordingly, all customers benefit, but the users of the Limited Cars benefit more.[49]

This greater benefit for the Limited Cars is a positive feature of the SDO solution and ensures its success. Customers want to use the least crowded cars, and the self-interest to do so will incentivize them to use the less crowded Limited Cars,[50] which are always at the ends of the platforms, and therefore positively impact dwell time.[51]

The math above also explains why 8-car trains are only expanded to 11 cars initially. If an existing 8-car train is expanded to 12 cars, the middle 4 Unlimited Cars, 50% of the length of the old 8-car trains, will still need to fit 50% of the customers. Moreover, if some of the customers that can use Limited Cars use Unlimited Cars instead, and some inevitably will, crowding will be *worse* than the present situation on Unlimited Cars. In contrast, the 4 Limited Cars on the front and back will only need to fit 25% of the existing customers each and have double the space they do now (4 cars/2 cars=2), clearly an undesirable result. The solution is to extend 8-car trains to 11 cars and have 5 Unlimited Cars, 3 A Cars and 3 B Cars. This means that customers that need

[49] For the 7 Train, the math works out differently because there are 7 Unlimited Cars not just 6 because the 7 Train has 11 cars currently instead of 10. The Limited Cars have 45% more space (3.636/2.5=1.4545), while Unlimited Cars at have 27% more space (63.63%/50%=1.2727). 8-car trains present different issues as discussed *infra.*

[50] The feature is at its highest importance at peak service hours, exactly the hours with the most savvy and regular customers that will quickly learn how to utilize the system to maximum advantage.

[51] In addition, the 50% of the customers that use Unlimited Cars will disembark 4 cars forward or back from the position on the platform at which they embarked. For example, customers that embark on the *fifth* car at an A Station (the middle of the platform), will disembark on the *first* car at the B station (the front of the platform).

Unlimited Cars will have 25% more space because they will have 5 cars available when they effectively used 4 cars on the old 8-car trains (5/4=1.25).[52] Customers that can use Limited Cars will have 50% more space because they will have 3 cars available when they effectively used 2 cars on the old 8-car trains (3/2=1.5).[53] Moreover, in respect of 8-car trains that use 75-foot cars, adding 3 cars still expands train length by 225 feet, close to the 240 foot expansion achieved by adding 4 60-foot cars to 10-car trains.[54]

For 8-car trains that presently use 60-foot cars, such as the L Train, there are 3 existing and/or future circumstances that will make it possible to extend the trains to 12 cars without overcrowding Unlimited Cars, possibly in the short term, but definitely in the medium term.

First, presently, some customers have an alternative of using one station or another because they live and/or work relatively equidistant from 2 subway stations. Accordingly, for example, customers that presently use an A Station at home and a B Station at work, when they could use a B Station relatively easily at home and/or an A Station at work, could start using a B station at home or an A Station at work so they can use the less crowded Limited cars. In other words, the implementation of the idea is dynamic and will result in some customers changing their present behavior to optimize to the new circumstance. If just under 10% of the Unlimited Car customers adopt this strategy, the extra capacity will balance evenly throughout the train. It is simply not possible to know how much this will occur in advance of implementation, although the implementation on the 7 Train will give insights on what occurs and a survey could be taken after implementation to determine the percentage of riders that adopted this strategy.

Second, in the medium term, as open-gangway cars are deployed, customers will be able to move between Limited Cars and Unlimited Cars after boarding to balance the train.

Third, 18.5% of rides occur through just 10 stations in Manhattan. In the medium term, the platforms can, and should, be extended at these 10 stations to enable customers that embark and disembark at them to use *any* car at both ends of their trip.[55] Accordingly, 9.25% of the customers that presently need to use the middle cars could instead use the end cars. This one change, *even without the prior 2 reasons*, would allow the customers to balance a train.

After a combination of the 3 circumstances sufficiently reduce demand for the middle cars on a line, the 12th car can be added to further expand capacity.

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[52] This also provides a 25% margin of error for customers that travel A to A or B to B use the middle cars anyway.
[53] Shortening SDO to 10 cars instead of 11 (for 8-car trains) results in 2 cars not platforming in the front and back, 25% of the length of the former train, and the exact amount of customers that can use A only or B only cars, leaving 6 cars to platform at all stations, which can hold 75% of all customers. This configuration puts *all* the excess capacity in the Unlimited Cars and allows customers to balance the train by choosing the middle cars even if they do not need to do so, but does so at the cost of reduced overall capacity and reduced incentive to use the Limited Cars.
[54] The differing train lengths require slightly different stopping places for the front of the trains. If the trains stop in the same place, the color-coded platform edging will need to extend back 235 feet from the front of a 14-car train using 60-foot cars so that all the doors on limited cars have the correct color-coded edging underneath them. But when an 11-car train using 75-foot cars with 3 Unlimited Cars at the ends (a total of 225 feet) stops at the same point, the color-coded edging will extend 10 feet into its fourth car boarding area and underneath its first set of doors incorrectly indicating to customers that the doors are Limited when they are actually Unlimited. The solution is to have the 14-car train stop 7 feet ahead of the stopping point for 11-car trains at A Stations (vice-versa at B Stations) so that the *first set of doors* on the 14-car train are at the edge of the platform *not the front of the train itself*. This way the edging only needs to extend 3 feet into the boarding area of the 4th 75-foot car, *not* under any of its doors.
[55] Even absent the balancing issue, the platform extensions are a good idea for the convenience of the customers as they highly leverage SDO by changing platforms at only 2% of the stations that serve 18.5% of all customers.

Finally, the addition of the 12th car, and SDO itself on non- open-gangway cars can and should be analyzed in the context of the current U.K. Industry Standards, which, in relevant part, state:

> **E.2 Multiple units without gangways**
>
> E.2.1 The use of SDO on multiple unit trains not fitted with inter-unit gangways might lead to a situation where passengers in one section of the train were unable to move to a part of the train where doors were available for egress to the platform. This is likely to be unacceptable both in respect of customer service, and safety, since the response of passengers in such a situation cannot be ensured.
>
> E.2.2 Where the decision is made to use SDO on these trains it may be done where:
>
> a) The platforms are always at least the length of the unit plus one vehicle (or one door) long.
>
> b) Announcements are made to allow passengers to move to a different unit at the previous station.
>
> c) A seat reservation system can help to assign passengers to the correct part of the train.
>
> E.2.3 All of these methods would require safety justification.

Rail Industry Standard RIS-2747-RST, §§ E.2; *see also* § 4.5.3 ("On trains with no corridor connections, the [Passenger Information System] shall provide information regarding which part of the train will be available for passengers to alight at a short platform as the train approaches the last station with a full length platform before that with a short platform.") As a threshold matter, the implementation of SDO will be widespread and the "rule" rather than the "exception." Accordingly, the concern regarding the response of passengers in § E.2.1 is a different because a customer will know that they failed to use the system correctly, so the reaction will be akin to a passenger missing their stop. It is also a mistake that customer are unlikely to make inadvertently more than once, and unlike service in which not platforming is irregular, customers will likely realize the problem before reaching their destination when their car does not platform at other stations, and be able to change cars or wait for the next train at a prior station. Finally, the service is essentially the same as the skip-stop service on the J/Z line, *particularly in the evening when customers must select the right train to reach their destination*. Similarly, customers already distinguish between local and express trains that operate on the same platforms that serve different stations at their destinations,[56] such as trains on the 6 and 7 lines, to reach their correct station, and they do so successfully without platform markings or signs, or information nearly as robust as is proposed herein. In short, customers *prove every day* that they can handle service limited to every other stop on the J/Z lines and service that is even less predictable on the lines that mix local and express service.

Even putting the foregoing aside, the methods in § E.2.2 apply or are sufficiently analogous to the SDO solution methods to justify implementation. Subsection "a" is met. Even on the 7 train, which has 15 vehicles, with 1 unit being 8-cars long and the other being 7-cars long, the platforms will all be at least 3 vehicles longer than the 8-car unit.[57] The same is true for all SDO unit configurations. Subsection "b" is not only met by announcements, but by all the signs and information devices described *supra*. Customers will have copious information in advance of

[56] Again, the evening service out of Manhattan is the most on point as that is when a customer could end up at the wrong station. In respect of mixed express and local service, choosing the wrong train is far more serious than it is for SDO as customers can end up *multiple* stations away from their intended destination, not just 1 stop away.
[57] RIS-2747-RST defines "unit" as "A permanently coupled group of vehicles. A unit may also be a single vehicle."

their destination station enabling them to choose the correct car for their desired station. Subsection "c" is not technically applicable, but the color coding, signage and information devices are, in effect, a system of assigning customers to the correct car, and the correct car is the relevant point of the seat assignment standard. In sum, this issue will, within days of implementation, be confined to tourists and other first-time users.

Even if the MTA is not convinced SDO can be implemented without open-gangway cars, it should not stop the SDO solution. Rather than abandon a solution that expands capacity as much as 65%, the MTA should implement SDO by making entire lines all open-gangway, one-by-one, by purchasing open-gangway cars or, if feasible, modifying existing cars to be open-gangway. While this would lengthen implementation, and cost more money, these impediments still pale in comparison to any other method that could hope to increase capacity by this order of magnitude. In this regard, the 2,310 cars that are proposed to be purchased herein could implement 100% open-gangway SDO service on up to 2 A Division lines and up to 4 B Division lines.

In any event, in the long-term, this issue disappears because only open-gangway cars will be acquired and deployed in the system under the SDO solution. In the meantime, the J/Z experience demonstrates customers can handle it.

g. Signaling and Signs. Obtaining the maximum benefit of the SDO solution requires optimizing signals. Presently signals on non-CBTC Lines are sensibly placed at the stations within 100 feet of both ends of each platform so that only 1 block is occupied when a train is stopped at a station. (Q&A 35.) With SDO trains being 215 to 240 feet longer, 2 signal blocks will be occupied when a train is stopped at a station: the present station block, and, at A Stations, the block behind the platform, and, at B Stations, the block in front of the platform. The existing blocks are 300 to 600 feet long. (Q&A 87.) Accordingly, when the relevant adjacent signal block (rearward for A Stations and forward for B Stations) is significantly longer than 300 feet, the station block should be expanded rearward at A Stations and forward at B stations so that only 1 block is occupied while a train is at a station.[58]

While signal optimization will be helpful, generally at every other stop, *the distance between trains will be the same as it is now*. If the first train on a track is at a B Station, the back of the train is at the back of the platform. The next station behind it will almost always be at an A Station, so if it has a train, the front of the train will be at the front of the platform, *the exact same spacing that exists presently*. When both trains advance 1 stop, the situation is reversed and the trains are 430 to 480 feet closer together because the first train is at an A Station with the extended part of the train beyond the back of the platform and the second train is at a B Station with the extended part of the train projected forward from the front of the platform. When the trains advance again, spacing reverts to the present spacing, and so on. Accordingly, even when train-bunching occurs, under SDO the trains revert to the present spacing at alternate stops.

[58] When blocks adjacent to the station in which the Limited Cars that do not platform will stop are 300 feet long (or close to it), it will not be worth moving a signal because it will be close to where the next signal is anyway. In addition, some platforms are longer than the trains are now, so there is flexibility at those stations regarding the point on the platform where trains will stop which can help reduce the need to relocate signals.

With respect to the magnitude of optimization, the system has 909 platforms.[59] It is assumed that half of the platforms (455) are center platforms and serve 2 tracks, so the 909 platforms serve 1,364 tracks. However, some platforms on the 1, 7, G, J/Z, L & M lines are either not part of the SDO solution or have CBTC already. The relevant platforms on those lines serve 238 tracks reducing the total to 1,126. It is further assumed that approximately 10% of the *second* signals from the platform will be 300 feet from the platform edge and will not need to be relocated, reducing the total by 112 to 1,014. Finally, it is assumed that at least 1 more line will have CBTC before SDO is fully implemented.[60] Using the 6 Line, which has platforms serving 41 tracks, for that purpose, the 1,014 amount is reduced to 973. Accordingly, a base of 1,000 platform/signal locations is used herein.[61] To the maximum extent possible, the signals should be changed in advance of SDO implementation. Where service levels do not permit that, the change can still be made in advance once open-gangway cars are obtained for a line as those cars independently increase capacity 10% and therefore permit 10% longer headways. Accordingly, open-gangway cars can bridge the transition period. A key unanswered question is how long it takes to relocate signals. (Q&A 63.) If it does not take long, there is little need to relocate signals in advance.

Finally, signs should be placed so operators know to stop the longer trains at the stations.

h. Lengthening Key Platforms. As mentioned *supra*, the MTA should consider lengthening 42 platforms at the most heavily trafficked stations, as well as 161 St.-Yankee Stadium and Mets-Willets Pt. so an entire 14-car train can platform.[62] It may also be worth expanding platforms for end-of-the-line stations, although as the system evolves to open-gangway cars, this will be of diminished importance.

i. Electric Power. Power is beyond the scope of the Challenge, (Q&A 20), but longer trains may require additional power, and the need should be analyzed and timely addressed.

5. Implementation Schedule Commencing January 2018 and Timeline Assumptions

The MTA effectively has no spare trains, so SDO cannot be implemented without expanding the fleet. Accordingly, the timing of the delivery of additional cars dictates the schedule. Delivery is estimated to take at least 4 years for the 7 and L Lines and at least 5.5 years to start deliveries for the other lines and approximately 5 years to finish. Accordingly, implementation of the service will start in 4 years and finish in 10.5 years. Specifically, service will start first with the 7 and L lines. Thereafter, for the A Division the order is 3, 2, 5, 4 and 6, and for the B Division, B, R, A, D, Q, N/W, E and F. The first 4 lines in the B Division are driven by consolidating the 75-foot cars into 3 lines, as well as extending the service to the Bronx and Manhattan with the B Line since the first 2 lines largely benefit Queens and Brooklyn.[63]

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[59] Majority of Conditions at Subway Station Platforms Improve or Stay at High Performance Levels Since Last Year, Straphangers Campaign, Mar. 7, 2013, at 1 ("This represents 28% of the total of 909 New York City Transit subway station platforms systemwide.") available at https://www.straphangers.org/reports/platforms2013.pdf.

[60] Even at the present pace, the MTA can probably implement 2 lines of CBTC in the next 10 years.

[61] It is conservatively assumed that Grade Time Control and Station Time Control signals cannot address the issue.

[62] The top 15 stations, in descending order, are Times Sq., Grand Central, 34 St-Herald Sq., Union Sq., 34 St.-Penn Station (IRT), 34 St.-Penn Station (IND), Fulton St., 59 St.-Columbus Circle; Lexington Ave/59 St., Lexington Ave./86 St., Lexington Ave.-53 St./51 St., Flushing-Main St., 47-50 Sts-Rockefeller Ctr., 74-Bway/Jackson Hts.-Roosevelt Ave., and 42 St.-Bryant Pk./5 Ave. Vertical circulation should be addressed when lengthening platforms. For Yankee Stadium and Mets-Willets, in the interim, trains could stop twice, schedules permitting.

[63] The D Line would take delivery of new 60-Foot cars that would initially operate as 10-car trains, while its 75-foot cars are transferred to the B, R and A Lines. After the first 3 lines are complete, the D itself will expand to SDO

There are 8 or 9 categories of work in implementation: (1) retrofitting SDO capability on 5,321 cars of the existing fleet;[64] (2) modifying car-signage; (3) acquiring 2,310 new cars; (4) station and platform work, including signs, platform cameras and monitors; (5) preparing storage tracks for the additional cars and longer trains; (6) optimizing signal blocks for the longer trains; (7) lengthening certain platforms (*optional, but recommended*); (8) educating customers upon implementation of each line, particularly the first line; and (9) additional power.[65] The key to success is accomplishing items 1-3 and 4-9 (the "Predicate Items") for each line, *before cars are manufactured under item 3 for each subway line*. Those dates are: 1/2022 (7); 7/2022 (L); 1/2024 (3 & B); 9/2024 (2 & R); 6/2025 (5 & A); 1/2026 (4); 3/2026 (D); 9/2026 (Q); 10/2026 (6); 3/2027 (N/W); 9/2027 (E); and 6/2028 (F). See column A of the chart *supra* at §D(4)(d). The detailed project plan and timeline, with key milestones in red, is set forth in Supplemental Materials §II(B), to which the Evaluation Committee and Judges are respectfully referred.[66]

Conservative assumptions are made throughout this application. Nevertheless, the scheduling assumptions are: (1) the MTA and contractors will commit the resources necessary to retrofit 3 trains a week with SDO and 1 train a week with electronic signage; (2) Kawasaki is able to re-start production promptly of R143 and R188 cars, with the modifications stated in the project plan, (Supp. Materials § II(B), Q1, 2018, Row 3), and deliver cars for service to start on the 7 and L lines in 2022; (3) the MTA is willing to continue to use the 75-foot cars through at least 2028, or refurbish them at a rate of 1 a week, or is willing to implement the 75-foot lines later and purchase new cars to do so; (4) the manufacturers of cars for the other lines can deliver 18 cars per month starting in Q3 2022; (5) the MTA is willing to change its current R211 order to be all open-gangway even if it requires waiting longer for delivery; (6) there is enough space to store the additional cars to be acquired or enough space can be created in a timely manner by using 1 or more of the 10 ideas in § D(4)(e) *supra*; (7) for full SDO implementation, the MTA is willing to implement SDO on lines that are not all open-gangway (partial implementation is possible if not); (8) for lines without CBTC, *required* signal block optimization can be timely completed; (9) any additional power needed from Con Edison can be timely provided; and (10) platform modifications and signage can be timely completed on a line-by-line basis.

6. Additional Information and Support Needed From the MTA

I need nothing from the MTA because I have zero capacity to implement the SDO Solution, rather the MTA will implement it through its personnel and cadre of contractors and suppliers.

7. Supplemental Material § II

The Evaluation Committee and Judges are respectfully referred to Supplemental Material § II for The detailed project plan and timeline with key activities and deadlines shown therein in red.

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when enough cars are delivered. The remaining B Division lines can be implemented in a different order. The Q Line was selected to be next because most of its signals will already be adjusted by SDO implementation on prior lines. Whatever the overall order, the B, R, A and D lines should be implemented sequentially.

[64] The 5,321 was determined by subtracting cars allocated to the 1, C, G, J, M & Z lines which will not use SDO.

[65] Power is outside the scope of the challenge, but it should be noted that the MTA may need to arrange for additional power before service begins and should coordinate closely with Con Edison to the extent required.

[66] The schedule and plan assume no environmental approvals are required except for: (1) station yard expansions; (2) maintenance shed expansions; and (3) reconstructing the Rockaway Branch line. It is further assumed that environmental impacts will be net positive given the benefits of rail mass transit. In light of the politics regarding the Rockaway Branch, notwithstanding the eminent sensibility of restoring it, that idea is *not* relied upon herein.

E. COST DETAIL

1. The Cost of SDO

The cost of the SDO solution, exclusive of both optional items below, but inclusive of contingencies and soft costs, is $11,762,186,250. If the MTA refurbishes the 2,132 75-foot cars, the cost is an additional $3,198,000,000. If platforms are lengthened, the cost is an additional $2,079,000,000.

2. Key Cost Components and How They Are Phased

There are 9 categories of work. The following chart shows each component, the estimated costs thereof (except for power) and the time period[67] in which the cost is anticipated to occur:

Cost Component	Cost	Begin Date	End Date
Retrofit SDO on 5,321 Cars and 1,221 Platforms	$200,000,000	1/1/2019	6/30/2023
Retrofit Cars with Electronic Signs	$53,000,000	4/1/2019	6/30/2023
Acquiring 1,104 Additional New Cars	$3,864,000,000	4/1/2020	6/30/2028
Optional – Refurbish 2,132 Cars	*$3,198,000,000*	*4/1/2019*	*6/30/2023*
Station and Platform Signage, Cameras and Edging	$1,235,140,000	10/1/2019	3/31/2028
Expand Storage and Lengthen Maintenance Sheds	$6,110,035,000	4/1/2019	9/30/2027
Signal Optimization	$300,000,000	7/1/2019	6/30/2027
Optional – Lengthen 42 Key Platforms	*$2,079,000,000*	*4/1/2019*	*9/30/2027*
Public Information and Implementation Assistance	$11,250.000	1/1/2018	6/30/2028
Total Cost without Options	**$11,762,186,250**		
Total Cost with *Car Refurbishment*	*$14,960,186,250*		
Total Cost with *Platform Lengthening*	*$13,841,186,250*		
Total Cost with *Both Options*	*$17,039,186,250*		

While the foregoing shows the time periods of the costs, the structure of implementation is to perform all of the Predicate Items either in advance of, or at or about the time of, implementation on each subway line in years 4 through 10. Car acquisitions constitute approximately 40% of the cost of the SDO solution, and the majority of those costs are incurred in years 4 through 10 upon delivery of the cars. Accordingly, almost 60% of the costs can be spread out over 10 years, but, given the inevitable delays that occur during construction, it is highly recommended that the MTA accelerate the Predicate Items as much as practicable to avoid situations in which cars are delivered, tested and ready, but the SDO solution cannot be implemented because Predicate Items are incomplete. Accordingly, it is expected that the costs will be phased relatively evenly over the 10-year period, or perhaps slightly front-loaded.

3. Supplemental Material § III

The Evaluation Committee and Judges are respectfully referred to Supplemental Material § III for a detailed description of each cost component explaining the basis for the estimated amounts used in the chart above, underlying assumptions and providing additional pertinent information.

F. CONCLUSION

How can the MTA not do this for New York?

[67] Soft costs for every category will begin in January 2018. The dates shown exclude soft costs.

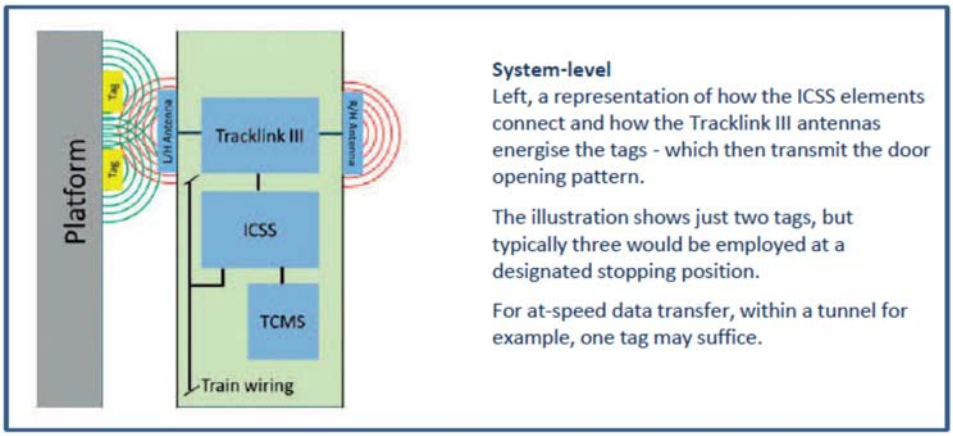
Section I – Technical Overview Supplemental Material § C(6)

Links describing the Sella Controls SDO/CSDE technology and London Underground project:

Technology: http://www.sellacontrols.com/rail-systems/mobile-solutions/selective-door-openingcorrect-side-door-enabling.

London Underground Project: http://www.sellacontrols.com/data/pp/pp054/docs/Tracklink_case_study0817.pdf

This is a simple schematic of train-based SDO/CSDE from the London Underground Project link above:



Specification sheet links:

SDO/CSDE Generally: http://www.sellacontrols.com/data/pp/pp054/docs/ASDO_CSDE.pdf

Reader: http://www.sellacontrols.com/data/pp/pp054/docs/TracklinkIIIReader0917.pdf

Tag: http://www.sellacontrols.com/data/pp/pp054/docs/TracklinkIIITag0917.pdf

Beacon: http://www.sellacontrols.com/data/pp/pp054/docs/TracklinkIIIBeacon0917.pdf

Related Specification Sheets, Certifications and Information: http://www.sellacontrols.com/downloads

Section II – Implementation Detail Supplemental Material - §D(6)

A. Three References for § D(1):

1. Iain Wilkinson, Business Development Manager, Sella Controls Ltd., iwilkinson@sellacontrols.com, Phone: 011 44 161-429-4500 Ext. 506, Carrington Field Street, Stockport, Cheshire SK1 3JN, UK
2. John Pope, Technical Sales Director, Petards Group PLC, john.pope@petards.com, Phone (direct): 011 44 191-440-110 4390, Princesway, Team Valley, Gateshead, Tyne & Wear NE11 0TU, UK
3. Joni Juuth, Business Area Manager, EKE-Electronics Ltd., joni.juuth@eke.com, Phone (direct): 011 358 50 348 3435, Piispanportti 7, 02240 Espoo, Finland

B. Project Plan Reference in § D(5) – Key Milestones in Red, *Optional Platform Lengthening is italicized*

Item	1st Quarter 2018	2nd Quarter 2018	3rd Quarter 2018	4th Quarter 2018
1-SDO Retrofit	Determine the SDO system(s) to use for all cars with train-based preferred over car-based; begin developing RFP for SDO equipment.	Issue RFP to potential vendors; review, clarify and vet RFPs received.	Select SDO vendor (and for the 7 and L Trains, do so in consultation and coordination with Kawasaki).	Provide draft contract to selected SDO vendor; finalize and sign contract.
2-Car Signs	Determine signage capabilities of existing cars and whether to retrofit cars without electric signs (approximately 200 trains that will use SDO have non-electronic signs); develop RFP to retrofit electric signs.	Issue RFP to potential vendors; review, clarify and vet RFPs received.	Select car signage vendor; provide draft contract to selected vendor; finalize and sign contract.	Vendor ramps up production of signs to MTA specifications.
3-New Cars	For the 7 and L Trains, start negotiations with Kawasaki for an order of 11.5 trains/173 cars, built to R188 specifications for the 7, and 9.5 trains/114 cars built to R143 specifications for the L, but: (a) be open-gangway; (b) have SDO; and (c) allow car-specific ticker messages and audio announcements. For the A Division, start a new RFP for 812 cars with the same capabilities above. For the B Division, modify the R211 to all open-gangway and include all modifications listed above and increase the options by 119 cars.	For the 7 and L Trains, provide draft contract to Kawasaki, possibly a modified version of the R188 and R 143 contracts, and begin negotiations. For the A Division, issue the RFP for the cars with an 10/15/18 deadline. For the B Division, set an 8/15/18 deadline for bidding on the R211 contract.	For the 7 and L Trains, execute contract with Kawasaki for complete delivery by 12/31/2021 for the 7 Train and 6/30/2022 for the L Train, with incentives for early completion/penalties for delays. For the B Division, review, clarify and vet bids for the R211 contract and award the contract.	For the 7 and L Trains, interact with Kawasaki on manufacturing issues as needed. For the A Division, review, clarify and vet responses to RFP. For the B Division, provide draft contract to R211 vendor, finalize and sign contract for deliveries to commence 6/30/2023 (a year after the L) at a rate of 252 cars/18 trains (14-car trains) per year, which will allow implementation of SDO on a new line every 7 months on average once deliveries start. Contract to have incentives for early completion/penalties for delays.
4-Station/ Platform Work	Prepare a survey of all stations to determine: (1) station signage requirements; (2) platform signage and tactile edging requirements; and (3) locations for platform cameras and monitors.	Conduct the survey of all stations for the signage, edging, cameras and monitors.	Continue survey. For the L line, schedule any updates needed for the OPTO cameras and monitors for the 15-month window between April 2018 and June 2019 in which the L train will be shut down in Manhattan.	Complete and analyze the results of the survey and determine whether some or all of the work will be done by contractors or MTA employees.
5-Train Storage	Begin analyzing yards to determine reconfiguration requirements for tracks and lengthening of maintenance sheds, expediting review of the Canarsie yard for the L Line, and study other train storage possibilities; assess the need for environmental compliance for the options.	Make a determination regarding reconfiguration of yards and lengthening of maintenance sheds, determine other storage methods to be used, the significance of environmental issues and whether other legal requirements need to be met. For the L Line, commence environmental scoping process and other necessary compliance processes.	To the extent necessary, begin Draft Environmental Impact Statements ("DEIS") work for maintenance shed and yard expansions, continue with any other legal compliance requirements including Title VI. To the extent storage solutions do not require environmental review, draft and issue RFPs for the work required. Formulate and issue an RFP for reconfiguring the Canarsie yard so the work can be done during the 2018-19 shut-down.	Issue DEIS as required for maintenance shed expansions and yard expansions, set comment period for 45 days, continue other legal compliance requirements (and complete them for the 7 and L Line yards and sheds). Review, clarify and vet responses to RFPs for storage work not requiring environmental review. Review, clarify and vet RFPs received for Canarsie yard reconfiguration, select vendor and provide draft contract to selected vendor.
6-Signals	Excluding certain stations on the 1, 7, G, J/Z, L & M lines, and excluding the 6 line platforms assuming they will be CBTC before SDO implementation, begin analysis of relocating signals adjacent to platforms.	Continue analysis of the need to relocate signals. Determine if any changes need to be made to CBTC control for the 7 and L Trains.	Complete the analysis of the signal relocation needs. If required, begin hardware or software modifications needed for CBTC control of the 7 and L Trains.	Draft and issue RFP for needed signal relocations.
7-Lengthen Key Platforms (optional)	*Begin analysis of lengthening 42 platforms at key stations, expediting review of the 7 platforms at Times Square and Grand Central and especially the L platforms at Union Square and 8th Avenue*	*Make a preliminary determination of lengthening 7 Train platforms at Times Square and Grand Central and other key stations, and a final determination for the L platforms at Union Square and 8th Avenue.*	*Make a final determination for the lengthening of platforms at other key stations and begin formulating RFP for the work on the 7 Train platforms at Times Square and Grand Central. Issue RFP for lengthening the platforms at Union Square and 8th Avenue so the work can be done during the 2018-19 shut-down.*	*For the Union Square and 8th Avenue platform extensions on the L Line, review, clarify and vet RFPs, select contractor and provide draft contract to selected contractor. Finalize and issue RFP for lengthening 7 Train platforms at Times Square and Grand Central. Begin formulating RFPs for the lengthening of platforms at other key stations.*
8-Educating Customers	Begin general information campaign about SDO, including press releases, web-site material and platform poster and interior subway car advertising; and community outreach with elected officials and advocacy groups.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.

Item	1st Quarter 2019	2nd Quarter 2019	3rd Quarter 2019	4th Quarter 2019
1-SDO Retrofit	Vendor ramps up production of SDO equipment and tags to MTA specifications.	Begin retrofitting 3 trains per week with SDO, starting with 7 and L Trains, and then proceeding to trains serving the lines in the order in which SDO will be implemented. Begin installing tags on all platforms to obtain the CSDE benefit immediately.	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line.	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line.
2-Car Signs	Vendor continues to ramp up production of signs to MTA specifications.	Begin retrofitting signs to trains at a rate of 1 per week, proceeding line-by-line in the order in which SDO will be implemented.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.
3-New Cars	For the 7 and L Trains and B Division trains, interact with Kawasaki and the B Division vendor on manufacturing issues as needed. For the A Division, select vendor and provide vendor with draft contract, finalize and sign contract for deliveries to commence 6/30/2023 at a rate of 252 cars/18 trains per year, which will allow implementation of SDO on a new line every 8 months on average once deliveries start. Contract to have incentives for early completion/penalties for delays.	Interact with manufacturers as needed.	Interact with manufacturers as needed.	Interact with manufacturers as needed.
4-Station/ Platform Work	Finalize and issue RFP for all materials needed for signage, edging, cameras and monitors. Issue RFP for installation of signage, edging, cameras and monitors with monitors at present conductor locations for use immediately, with provisions to add monitors easily to locations as an A or B platform.	Review, clarify and vet RFPs received. Select vendors for materials and signage, edging, camera and monitor installation and provide draft contract to selected vendors.	Finalize and sign contracts for materials and signage, edging, camera and monitor installation.	Begin platform camera and monitor installation.
5-Train Storage	To the extent yards and sheds will be expanded, collect comments on the DEIS, review and incorporate as appropriate, issue Final Environmental Impact Statements ("FEIS") and complete any other legal compliance requirements. Select vendor(s) for storage work not requiring environmental review and provide draft contract(s) to selected vendor(s). Finalize and sign contract for Canarsie yard reconfiguration to commence 4/1/19.	Draft and issue RFPs for the yards and sheds that will be expanded. Finalize and sign contracts for storage work not requiring environmental review. Begin Canarsie yard reconfiguration.	Review, clarify and vet RFPs received for maintenance shed expansions and yard expansions. Begin storage work that did not require environmental review. Continue Canarsie yard reconfiguration.	Finalize and sign contracts for maintenance shed expansions and yard expansions. Continue storage work that did not require environmental review and Canarsie yard reconfiguration
6-Signals	Review, clarify and vet RFPs received for needed signal relocations, select vendor(s) and provide draft contract(s).	Finalize and sign contract(s) and have contractors mobilize for the work.	Commence relocations to the maximum extent possible that signals can be moved in advance working on lines in the order in which SDO will be implemented.	Continue relocating signals.
7-Lengthen Key Platforms (optional)	*Finalize and sign contract for platform extensions at Union Square and 8th Avenue on the L Line to commence 4/1/19. Review, clarify and vet RFPs received for lengthening 7 train platforms at Times Square and Grand Central and select vendor. Finalize and issue RFP for lengthening platforms at other key stations.*	*Commence platform extensions at Union Square and 8th Avenue on the L Line. Provide draft contract to selected contractor for lengthening 7 train platforms at Times Square and Grand Central and finalize and sign contract. Review, clarify and vet RFPs received for lengthening platforms at other key stations.*	*Continue platform extensions at Union Square and 8th Avenue on the L Line. Commence platform extensions at 7 train platforms at Times Square and Grand Central. Select vendor(s) for lengthening of platforms at key stations and provide draft contract(s) to selected vendor(s).*	*Continue platform extensions at Union Square and 8th Avenue on the L Line and at the 7 train platforms at Times Square and Grand Central. Finalize and sign contract for lengthening platforms at other key stations.*
8-Educating Customers	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.

Item	1st Quarter 2020	2nd Quarter 2020	3rd Quarter 2020	4th Quarter 2020
1-SDO Retrofit	Continue to retrofit 3 trains per week finish installing tags to obtain the CSDE benefit immediately for each line.	Continue to retrofit 3 trains per week.	Continue to retrofit 3 trains per week.	Continue to retrofit 3 trains per week.
2-Car Signs	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.
3-New Cars	Interact with manufacturers as needed.	Interact with manufacturers as needed.	Interact with manufacturers as needed.	Interact with manufacturers as needed.
4-Station/ Platform Work	Continue platform camera and monitor installation, begin taking deliveries of materials needed for signage and edging.	Continue platform camera and monitor installation, and continue taking deliveries of materials needed for signage and edging.	Continue platform camera and monitor installation, and continue taking deliveries of materials needed for signage and edging.	Continue platform camera and monitor installation; continue taking deliveries of materials needed for signage and edging and begin installing signage bases, brackets and other items needed for eventual display of the signs themselves.
5-Train Storage	Begin maintenance shed expansions and yard expansions. Continue storage work that did not require environmental review and Canarsie yard reconfiguration.	Continue maintenance shed expansions and yard expansions, storage work that did not require environmental review and Canarsie yard reconfiguration.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review and complete Canarsie yard reconfiguration.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.
6-Signals	Continue relocating signals.	Continue relocating signals.	Continue relocating signals.	Continue relocating signals.
7-Lengthen Key Platforms (optional)	Continue platform extensions at Union Square and 8th Avenue on the L Line and at the 7 train platforms at Times Square and Grand Central. Commence platform extensions at other key stations.	Continue platform extensions at Union Square and 8th Avenue on the L Line and at the 7 train platforms at Times Square and Grand Central, and other key stations.	Complete platform extensions at Union Square and 8th Avenue on the L Line and continue platform extensions at the 7 train platforms at Times Square and Grand Central, and other key stations.	Complete platform extensions at the 7 train platforms at Times Square and Grand Central, and continue platform extensions at other key stations.
8-Educating Customers	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.

Item	1st Quarter 2021	2nd Quarter 2021	3rd Quarter 2021	4th Quarter 2021
1-SDO Retrofit	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line.	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line.	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line.	Continue to retrofit 3 trains per week and install tags to obtain the CSDE benefit immediately for each line. Test tags on the 7 Line.
2-Car Signs	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week. Test signs on the 7 Trains.	Continue retrofitting car signs at a rate of 1 train per week.
3-New Cars	Interact with manufacturers as needed.	Interact with manufacturers as needed, take delivery of 7 Train cars and begin testing them.	Interact with manufacturers as needed, take delivery of 7 Train cars and continue testing.	Interact with manufacturers as needed, finish taking delivery of 7 Train cars and continue testing.
4-Station/ Platform Work	Continue: (1) platform camera and monitor installation; (2) deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Begin installing signs and edgings on 7 Line.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Complete installing signs and edgings on 7 Line; test 7 Line cameras and monitors.
5-Train Storage	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review and complete Corona yard reconfiguration and expansion.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review and complete any expansion of the Canarsie yard and East New York shed.
6-Signals	Continue relocating signals.	Continue relocating signals.	Continue relocating signals make any required adjustments to CBTC for the 7 Line.	Continue relocating signals; Test CBTC changes on the 7 Line.
7-Lengthen Platforms	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*
8-Educating Customers	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress.	Continue information campaign, keeping interested parties informed of the progress. Ramp up publicity on the 7-Line implementation city-wide, locally in Queens and at 7 Line stations.	Continue information campaign, keeping interested parties informed of the progress. Continue with specific publicity for the 7 Line implementation, increasing intensity as implementation approaches.

Item	1st Quarter 2022	2nd Quarter 2022	3rd Quarter 2022	4th Quarter 2022
1-SDO Retrofit	Continue to retrofit 3 trains per week. Lengthen trains on the 7 Line and Implement SDO.	Continue to retrofit 3 trains per week. Test tags on the L Line.	Continue to retrofit 3 trains per week. Lengthen trains on the L Line and Implement SDO.	Continue to retrofit 3 trains per week.
2-Car Signs	Continue retrofitting car signs at a rate of 1 train per week. Test signs on L Trains.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.	Continue retrofitting car signs at a rate of 1 train per week.
3-New Cars	Interact with manufacturers as needed, complete testing of 7 trains, and take delivery of L Train cars and begin testing.	Interact with manufacturers as needed, finish delivery of L Train cars and continue testing.	Interact with manufacturers as needed, complete testing of L Trains.	Interact with manufacturers as needed.
4-Station/ Platform Work	Continue: (1) platform camera and monitor installation; (2) deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Begin installing signs and edgings on L Line.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Complete installing signs and edgings on L Line; test L Line cameras and monitors.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.
5-Train Storage	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.
6-Signals	Continue relocating signals and make any required adjustments to CBTC for the L Line.	Continue relocating signals; Test CBTC changes on the L Line.	Continue relocating signals.	Continue relocating signals.
7-Lengthen Platforms	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*
8-Educating Customers	Continue information campaign. Maximum publicity for the 7 Line, have MTA personnel at every station to assist customers and answer questions the week of implementation.	Continue information campaign. Ramp up publicity on the L Line implementation somewhat city-wide, but much more locally in Brooklyn and at L Line stations, increasing intensity as implementation approaches.	Continue information campaign. Maximum publicity for the L Line, have MTA personnel at every station to assist customers and answer questions the week of implementation.	Continue information campaign, keeping interested parties informed of the progress.

Item	1st Quarter 2023	2nd Quarter 2023	3rd Quarter 2023	4th Quarter 2023
1-SDO Retrofit	Continue to retrofit 3 trains per week.	Finish retrofitting trains.		Test tags on the B and 3 Lines.
2-Car Signs	Continue retrofitting car signs at a rate of 1 train per week.	All signs implemented in all cars and fully tested.		
3-New Cars	Interact with manufacturers as needed.	Interact with manufacturers as needed.	Take delivery of and testing open-gangway cars for A & B Divisions as they are delivered.	Continue taking delivery of and testing open-gangway cars for A & B Divisions.
4-Station/ Platform Work	Continue: (1) platform camera and monitor installation; (2) deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Begin installing signs and edgings on B and 3 Lines.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Complete installing signs and edgings on B and 3 Lines; test B and 3 Line cameras and monitors
5-Train Storage	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review and complete any expansion of the B and 3 Lines yards and sheds	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review and complete any expansion of R and 2 Lines yards and sheds.
6-Signals	Continue relocating signals.	Continue relocating signals.	Continue relocating signals; relocate final signals necessary on the B and 3 Lines.	Continue relocating signals; test all signals on the B and 3 Lines.
7-Lengthen Platforms	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations; ensure B and 3 Line platforms are complete.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations; ensure R and 2 Line platforms are complete.*
8-Educating Customers	Continue publicity, keeping the press and public informed of the progress.	Continue publicity, keeping the press and public informed of the progress.	Continue publicity, keeping the press and public informed of the progress.	Continue publicity, keeping the press and public informed of the progress. Ramp up publicity on the B and 3 Line implementations somewhat city-wide, but much more locally in the Bronx, Manhattan and Brooklyn and B and 3 Line stations, increasing intensity as the implementation date approaches.

Item	1st Quarter 2024	2nd Quarter 2024	3rd Quarter 2024	4th Quarter 2024
1-SDO Retrofit	Put 30 new open-gangway cars (3 trains) in service on the N/W line and transfer 24 75-foot cars to the B Line; put 90 new open-gangway cars (9 trains) in service on the D Line and transfer 66 75-foot cars to the B Line; lengthen all trains on the B Line to 11 with 75-foot cars and implement SDO on the B Line. Lengthen trains on the 3 Line and implement SDO.	Test tags on the R and 2 Lines	Put 150 new open-gangway cars (15 trains) in service on the D Line and transfer 110 75-foot cars to the B Line; lengthen all trains on the R Line to 11 with 75-foot cars and implement SDO on the R Line. Lengthen trains on the 2 Line and implement SDO.	
2-Car Signs				
3-New Cars	Continue taking delivery of and testing open-gangway cars for A & B Divisions.	Continue taking delivery of and testing open-gangway cars for A & B Divisions.	Continue taking delivery of and testing open-gangway cars for A & B Divisions.	Continue taking delivery of and testing open-gangway cars for A & B Divisions.
4-Station/ Platform Work	Continue: (1) platform camera and monitor installation; (2) deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Begin installing signs and edgings on R and 2 Lines.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Complete installing signs and edgings on R and 2 Lines; test R and 2 Line cameras and monitors	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs.	Continue: (1) platform camera and monitor installation; (2) taking deliveries of materials needed for signage and edging; and (3) installing signage bases, brackets and other items needed for eventual display of the signs. Begin installing signs and edgings on A and 5 Lines
5-Train Storage	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.	Continue maintenance shed expansions and yard expansions and storage work that did not require environmental review.
6-Signals	Continue relocating signals; relocate final signals necessary on the R and 2 Lines.	Continue relocating signals; test all signals on the B and 3 Lines.	Continue relocating signals.	Continue relocating signals; relocate final signals necessary on the A and 5 Lines.
7-Lengthen Key Platforms (optional)	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations.*	*Continue platform extensions at key stations ensure A and 5 Line platforms are complete.*	*Continue platform extensions at key stations.*
8-Educating Customers	Continue information campaign, keeping interested parties informed of the progress. Maximum publicity for the B and 3 Lines, have MTA personnel at every station to assist customers and answer questions the week of implementation.	Continue information campaign, keeping interested parties informed of the progress. Ramp up publicity on the R and 2 Line implementations city-wide and R and 2 Line stations, increasing intensity as the implementation date approaches.	Continue information campaign, keeping interested parties informed of the progress. Maximum publicity for the R and 2 Lines, have MTA personnel at every station to assist customers and answer questions week of implementation.	Continue information campaign, keeping interested parties informed of the progress.

For 2025 through completion in 2028, the pattern in each category is as follows: (1) Test tags on the upcoming line to be implemented in the quarter before implementation; (2) no additional action required, all electronic car signs are retrofit by the second quarter of 2023; (3) test new open-gangway cars as delivered; (4) begin installing signs and color-coded platform edging on the upcoming line 2 quarters before implementation, complete the quarter before and test platform cameras and monitors the quarter before; (5) ensure yard and shed expansions, if any, for the upcoming line is complete 3 quarters ahead of implementation (so there is room to store the new trains as they arrive); (6) relocate all remaining signals on the upcoming line 2 quarters ahead of implementation and test the signals the quarter before; (7) ensure any platforms that are being lengthened are complete 3 quarters before implementation because signs and edgings are installed 2 quarters ahead; and (8) publicity for the upcoming lines begins in the quarter before and ramps up through implementation and additional MTA personnel are always present upon implementation to help customers adapt (this need decreases as more lines are implemented). The remaining lines will be implemented shortly after enough cars are delivered to enable SDO service as follows: A and 5 – 2nd Quarter 2025 (all 3 remaining 75-foot car lines are now fully-SDO); 4 – 1st Quarter 2026; D – 1st Quarter 2026; 6 - 4th Quarter 2026; Q – 3rd Quarter 2026; N/W 1st Quarter 2027; E – 3rd Quarter 2027; and F – 2nd Quarter 2028, whereupon the project is complete.

III. Cost Detail Supplemental Material for § E

1. Retrofitting SDO Capability on 5,321 Cars and 1,221 Platforms - $200,000,000

a. Cars. This analysis uses Sella Controls' list pricing.[1] The current list price for readers is £3,500 and the list price for platform tags is £400. For the sake of simplicity, it will be assumed that *every* car will have a reader even though only two readers are needed when a train-based system is used.[2] Sella also recommends purchasing 5% more readers than will be installed so that if a reader fails, it can be replaced out with a spare while repairs are made. On that basis, 5,588 readers will be ordered for a total price of £19,558,000. It will further be assumed that other ancillary materials will be needed, and the above cost is therefore increased by 10%, £1,955,800, to a total of £21,513,800. Using a conversion rate of £1 to $2,[3] the cost in dollars is $43,027,600. It takes 1 week to install readers on a 10-car train. Assuming 4 electricians at the prevailing wage of $110.35 per hour, the labor cost would be $17,656 per 10-car train, or $9,235,853 for the 5,231 cars. Materials and labor costs combined total $52,263,454. Soft costs of 25% add $13,065,864, bringing the total to $65,329,318. Finally, a 20% contingency of $13,065,864 brings the total to $78,395,182, say **$80,000,000**.

b. Platform Tags. Platform tags are passive devices and the only failures Sella recalled were instances in which physical damage occurred to a reader.[4] Moreover, tags are specific to stations, although many stations will use the same configuration allowing tags to be grouped. Nevertheless, it is assumed that a backup tag will be ordered for each tag ordered. For car based SDO, 2 tags would be ordered for each platform, one for the front and one for the rear (at B Stations it is necessary, but even at A Stations it adds safety), for a total of 4 tags per platform including the spares. As there are 1,221 platforms,[5] the material cost for tags is £488,400. The tags can be installed numerous ways including with adhesives. Accordingly, the cost of ancillary materials is nil, but £10,000 is nevertheless added, to bring the total to £498,400. At £1 to $2, the cost is $996,800. The Sella website states that tags can be installed in 5 minutes. It is assumed it will take 1 hour to install 2 tags at each platform by a heavy construction carpenter at the rate of $102.29 per hour, so the labor cost would be $103 per platform, or $125,763 for 1,221 platforms. Materials and labor costs combined total $1,122,563. Further soft costs of 25%, $280,641, increase the total to $1,403,204. Finally, a contingency of 20%, $280,641, brings the total to $1,683,845, say $1,700,000. Train-based SDO utilizes 3 tags per platform, using the same assumptions above regarding spares, brings the total to 6, or 50% more than car-based. If the MTA installed both types at every platform, it would add another $2,550,000 for train-based tags. The total for tags is therefore **$4,250,000**.

c. Distance and GPS-Based Methods. In the event the MTA decides to use the GNSS and distance-based systems, the cost would increase. Petards offers a system that combines GNSS and distance based systems (using axle rotations) at a cost of approximately £5,000 per car, or 43% more than the readers for the Sella system. Adding 43%, $34,400,000 to the $80,000,000 results in a cost of **$114,400,000**. So, if the 2 systems were both used, the total cost would be $198,650,000, say **$200,000,000**.

2. Retrofitting Cars with Electronic Signs - $53,300,000

Under SDO, it will be helpful for cars to display their status as A or B cars and show the next stop for *that car* on electronic information display signs and strip maps. They would be installed on 755 R62 cars and 752 R46 cars, and 625 R68/R68A cars, a total of 2,132 cars. In connection with the installation of strip maps on the 2 and 5 trains, it was reported "It will take several months to install the strip maps, and the cost cannot be determined until the work is done, an MTA spokesman said."[6] I am in no better position, so the MTA should refer to its experience on the strip maps. Nevertheless it is assumed that the cost to retrofit electronic signage is $25,000 per car, inclusive of materials, labor, soft costs and contingencies, or **$53,300,000** for 2,132 cars.

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[1] Volume pricing would be negotiated for the quantities the MTA would procure.
[2] In respect of train-based systems, the £4,000,000 London Underground contract, completed on time and on budget, involved 4 lines and 191 trains 7-9 cars long. Even allocating the entire £4,000,000 to the trains, the price per train is £20,942, less than £3,500 per car.
[3] The current exchange rate is $1.32/£1. Since 1981, the pound has only exceeded $2.00/£1 in 2007-08, when it peaked at $2.09.
[4] The example given was a mainline railway freight train not properly securing a load damaging the platform and the tag.
[5] 1,221 was calculated by adding the 95 platforms for the 7 and L Lines to the 1,126 total used in §D(4)(g) of the main application.
[6] https://www.newsday.com/news/new-york/mta-plans-upgraded-electronic-strip-maps-for-2-and-5-lines-1.11466508, retrieved 11/10/17.

3. Acquire New Cars - $3,864,000,000, and Refurbish Non-NTT Cars (Optional) - $3,198,000,000

New Cars. The MTA will need 985 A Division cars and 1,325 B Division cars. 1,206 of the B Division cars are already ordered, so 1,104 additional cars are needed. The MTA capital plan budgets $2,956,000,000 for 940 B Division cars, $3,144,680 per car. Adding SDO will increase the cost of the car by an estimated $50,000 bringing the cost per car to approximately $3,200,000. Assuming higher costs for open-gangway cars and other contingencies, the cost for all 1,104 additional cars is $3,500,000 per car for a total of **$3,864,000,000**.[7]

Refurbishing Cars. While this is not included within the SDO solution being proposed, the MTA could refurbish some or all of the 755 R62 cars, 752 R46 cars, and 625 R68/R68A cars to extend their useful life.[8] It should be noted that the Regional Plan Association recommends this approach for at least the R62 and R68 cars for CBTC purposes (which should absolutely be part of the refurbishment), noting the success of other agencies in doing so.[9] In the event the MTA decides to do so, the cost is assumed to be $1,000,000 per car, based on the "not to exceed" cost of $72,970,493 Los Angeles is paying to refurbish 74 cars,[10] exclusive of contingencies, or approximately $1,000,000 per car. Adding 20% for contingencies, the amount is $1,200,000 per car, and further adding 25%, $300,000, for soft costs, the cost is $1,500,000 per car or *$3,198,000,000* for 2,132 cars.[11]

4. Station and Platform Signage, Cameras and Edging - $1,235,140,000

The work at the stations and platforms, including signage, platform cameras and monitors and color-coded tactile platform edging obviously has numerous components making estimates difficult in some areas. However, some components are known. For the platform cameras and monitors, it cost $10,000,000 to do the work on the L Line in 2003 dollars. (Q&A 21.) According to the Bureau of Labor Statistics inflation calculator,[12] inflation since January 2003 is 36%, adjusting the OPTO project cost up to $13,600,000, or $283,000 for each of the 48 platforms on the L Line. Additionally, the SDO solution recommends cameras the entire length of the platform and additional monitors and monitor locations to accommodate existing and future locations from which doors will be operated. On the other hand, technology costs have dropped significantly since 2003. The per platform cost will be increased 20% for contingencies to $340,000 per platform, or **$415,140,000** for 1,221 platforms.

For station and platform signage and platform edging, I am unable to locate an analogous situation in the public record and my request regarding replacing the yellow tactile edging with a different colored material was denied. (Q&A 47.) Literally this work is putting up static, traditional, conventional boring signage (not electronic) and replacing the yellow tactile platform edging with the exact same material, but of a different color. So, completely assuming an average of $2,000,000 per station, inclusive of soft costs. There are 472 stations in the system, but 62 on the 1, G, J, M and Z lines will not be part of the solution, leaving 410 stations. Accordingly, the "estimated" cost is **$820,000,000**.

5. Storage for Longer Trains and Longer Maintenance Facilities - $6,110,035,000

Train Storage. The system presently has "114 miles [of] yard storage." Q&A 120. Assuming 20% is lost because it is impossible to use 100% of the track when operating, 91.2 miles of yard storage track is available.[13]

The present fleet is 27.83 miles long in the A Division and 43.94 miles long in the B Division, for a total of 71.77 miles. Based on the present train schedules, approximately 4.23 miles of A Division cars and 7.5 miles of

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[7] No soft costs are added because the work for the trains has largely been completed already.

[8] A decision should be made immediately as refurbishment delays could impact the implementation schedule. The contract should provide for a rate of 1 car per week being refurbished (once refurbishment is fully ramped up) in order to meet the schedule. Also, the MTA could buy time by implementing 75-foot car lines last instead of first, but if it does so, as a matter of transit equity, the 2 Line should be implemented before the 3 Line in the A Division in order to bring the expanded SDO service to the Bronx more quickly.

[9] Moving Forward, Accelerating the Transition to [CBTC] for New York City's Subways, Regional Plan Association, May 2014 at 65-67, available at: http://library.rpa.org/pdf/RPA-Moving-Forward.pdf

[10] https://metro.legistar.com/LegislationDetail.aspx?ID=2832809&GUID=4A40B260-6BC8-43B0-9F06-08B7047DFCEA&FullText=1, retrieved 11/10/17. The trains from Los Angeles were built in the 1990s.

[11] The $53,300,000 cost for the electronic signs would not occur if the $3,198,000,000 refurbishment is undertaken.

[12] https://www.bls.gov/data/inflation_calculator.htm

[13] This amount assumes no cars are stored in shops. (Q&A 144, "Trains are not stored in maintenance shops"), but trains are inherently stored in shops to some degree. Second Avenue Subway Final Environmental Impact Statement, Vol. 1, at 2-25, n.1, April 2004 (assuming 1 of 33 trains would be in the overhaul shop when determining storage requirements).

B Division cars operate overnight, for a total of 11.73 miles. Accordingly, the present overnight storage need is 60.04 miles of cars, leaving 31.1 miles of track available for overnight storage.

SDO adds 985 A Division cars for a total of 9.52 miles. For the B Division, the increase is 1,379 cars for a total of 15.67 miles, a total increase of 25.19 miles. Approximately 4 miles of the cars will be in service overnight, so the net storage requirement is approximately 21 miles, 10 miles less than the 31 miles available.[14]

In light of the foregoing, there is adequate storage for the additional cars, but the storage yards are presently optimized for 8, 10 and 11-car trains. As a result, storage yards will need to be reconfigured to handle the longer trains. It is assumed that every yard will need to be reconfigured and that every one of the 14 maintenance facilities will need to be lengthened so that a train does not have to be decoupled for service.

For track reconfigurations, each yard will have to be analyzed to determine its needs, but the work started in 2013 and completed in 2016 on the MTA's Johnson Avenue yard for the Long Island Rail Road ("LIRR") that cost $27,000,000 provides a basis to estimate the costs.[15] The contractor stated the work:

> included realigning and re-profiling 5,500 feet of track and 350 feet of the yard lead track; installing four new track switches; raising the elevation of the eastern half of the yard; developing an underground track support system for a portion of the yard lead track under the AirTrain building; constructing a 1,230-LF retaining wall system; and implementing new lighting, public address, and closed-circuit television systems. Because of the location of the future platform, an existing utility duct bank and manhole system containing critical railroad power, signal, and communication cables also needed to be relocated.

Adding 7% to the $27,000,000 to adjust for inflation from 2013, the Johnson Avenue yard project would now cost $28,890,000. Adding 20%, $5,778,000, for contingencies, the contract amount is $34,668,000, and adding another 25%, $8,667,000, for soft costs, the cost is $43,335,000 per yard, or **$910,035,000** for 21 yards.

Maintenance Facilities. A new LEED certified maintenance shed was built in the Corona yard in 2006 for $168,000,000, inclusive of ancillary facilities.[16] Based on 24% inflation since the start of work in 2002, the cost now is approximately $233,520,000. The facility can service 5 11-car A-Division trains 563 feet long, but under SDO, A Division sheds will need to service trains 717 feet long, 27% longer than the Corona shed. Accordingly, the cost of building an entirely new A-Division sheds increases by 27%, or $63,050,400, to $296,570,400. Adding 25%, $74,142,600, for soft costs, the total is $370,713,000. Based on the MTA's 2015-34 Capital Needs Assessment, it is assumed that the MTA will demolish the 240th Street and Livoina maintenance sheds, which collectively have 10 service tracks, and replace them at a cost of *$741,426,000*. The Corona shed would be lengthened by 4 cars, or 36%, for a cost of *$133,456,680* (36% of $370,713,000). The 4 remaining sheds will be lengthened by 4 cars/36% also, but they collectively have 27 service tracks, the equivalent of 6.75 Corona yards.[17] Accordingly, the $133,456,680 amount is multiplied by 6.75, not just the number of sheds. Accordingly, for the remaining sheds, the expansion cost is calculated at *$900,832,590* ($133,456,680 x 6.75). Adding the italicized amounts in this paragraph, the A Division cost is $1,775,715,270.

I lack the information necessary to make calculations similar to those made for the A Division, so the A Division amount and assumptions, particularly the demolition and replacement of two sheds, will be used, adjusting for the facts that: (1) B Division trains will generally be 840 feet long, approximately 17.6% longer than the A Division trains; and (2) the B Division has 21.7% more cars than the A Division (3,523/2,895=1.2169). (Q&A A and B Division Car Assignment Attachments at Shop Assignments.) Increasing the A Division amount proportionally the B Division cost is $2,541,389,488 (1,775,715,270 x 1.176 x 1.217).

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[14] In a Q&A it was stated that mainline track is used for overnight storage "in selected instance[s]". (Q&A 144.) Accordingly, the calculations above do not rely on mainline storage. In the event there is not adequate storage, I have suggested several alternatives above, most particularly, the end-of-line shuttle service which has significant operational benefits, that can be used in the event storage is inadequate at any particular yard (as opposed to the whole system), and in fact can be used even without the SDO solution.

[15] The MTA should consider implementing the SDO solution on the LIRR and Metro-North commuter rail lines.

[16] Accordingly, all calculations below include a proportional amount of ancillary facilities, not just maintenance sheds.

[17] While no new sheds need to be added to the system, in order to maintain present service standards, from an operational point of view, additional service staff must be hired. Again, the SDO solution costs no operations workers their jobs, rather, however modestly, the SDO solution only adds living-wage, middle-class, jobs.

Accordingly, assuming that no efficiencies are obtained for yard work already planned and allocating the entire cost of shed work to the SDO solution even though the capital assessment foresees work on maintenance facilities, the total cost of longer maintenance sheds is $4,317,104,758 prior to contingencies. Adding 20%, 863,420,952, for contingencies, the total for both divisions is $5,180,525,710, say **$5,200,000,000**.

6. Signal Optimization - $300,000,000

The issue here is the cost to optimize signals so that trains at stations occupy 1 signal block only. It is assumed that 1,000 signals need to be relocated. The MTA's response to my question on the time and expense in relocating 1 signal 250 to 300 feet was to provide the information to the best of my ability. (Q&A 62 & 63.)

A 2010 cost estimate for intercity rail service from Chicago to Iowa City, Iowa estimated the labor cost of installing a "distant signal" at $50,000, including its power feed.[18] Given that both installation and removal will occur here, the amount is doubled to $100,000. Assuming some new materials will be needed due to damage during the work or for other reasons, $20,000 for materials is added, for a total to $120,000. Adding 13%, $15,600, for inflation since 2010, raises the amount to $135,600. Adjusting for the fact that the work is in New York, not Chicago, 44%, $59,664, is added for an amount to $195,264.[19] Next, 25% for soft costs of $48,816 is added bringing the amount to $244,080. Finally, adding 20%, $48,816, for contingencies, the cost of relocating 1 signal comes to $292,896. Accordingly, relocating 1,000 signals costs $292,896,000, say **$300,000,000**.

7. Lengthening Key Platforms (Optional) - $2,079,000,000

It is recommended that platforms be lengthened, and vertical circulation proportionately increased, in the 10 busiest stations serving 18.5% of subway rides.[20] The top 10 stations have 44 platforms, all below-ground, but 2 serve only the J/Z trains and 26 are center platforms. The closest relevant information I could locate is the approximately $550,000,000 cost of adding the 10th Avenue station with 2 platforms to the 7 Line. Assuming 30% of that cost is attributable to the 2 platforms and vertical circulation,[21] the cost is $165,000,000, or $82,500,000 per platform. As 40% enlargements are contemplated, the cost per platform enlargement is $33,000,000. Adding 25%, $8,250,000, for soft costs, the cost is $41,250,000, and adding 20%, $8,250,000, for contingencies, the total cost is $49,500,000 per platform, or $2,079,000,000 for 42 platforms.

8. Public Information and Implementation Assistance - $11,250,000

I believe the MTA's existing staff can handle this, but nevertheless funding 1 additional employee at $250,000 a year, and 2 additional employees at $125,000 a year costs **$5,000,000** over 10 years.

There will also be additional MTA station agents present when SDO is implemented to help customers. It is assumed that an average of 2 shifts of 4 employees per station for one week for each line.[22] There are 410 stations, which results in 3,280 total work weeks. The wage is $47.12, including supplemental benefits, or 1,884.80 per week, for a total cost of $6,182,144, say **$6,250,000**.[23]

Finally, the subway map will be updated as SDO rolls out on each line. The MTA can do this in house.

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[18] https://iowadot.gov/iowarail/application/cecostestimate.pdf @ pdf p. 127, *ll.* 1-2.

[19] https://www.numbeo.com/cost-of-living/compare_cities.jsp?country1=United+States&country2=United+States&city1=Chicago%2C+IL&city2=New+York%2C+NY&tracking=getDispatchComparison, retrieved 11/11/2017.

[20] The next five busiest stations, Yankee Stadium and Mets-Willets should also be done for customer convenience.

[21] To the extent 30% is an inaccurate assumption, the final cost amount should be adjusted ratably.

[22] The first few lines will average 4 to 6 employees per station. Later implementations will have 2 employees per station as customers will be more educated from prior implementations. Also, some stations have more than one line and will have employees on hand on multiple implementations. It is assumed that all of the foregoing averages to 4 employees per station overall.

[23] There is not a relevant category on the Prevailing Wage Schedule. $47.12 is double the Station Agent wage reported here: https://www.glassdoor.com/Hourly-Pay/Metropolitan-Transportation-Authority-Hourly-Pay-E366592.htm, retrieved 11/11/2017.