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Second Avenue Subway - A Status Report

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6/13/2008

ABSTRACT: The Second Avenue Subway is the first major subway construction project in New York City to be undertaken in the 21st Century. The DMJM Harris*Arup Joint Venture was hired by MTA Capital Construction in December 2001, to prepare conceptual design, preliminary and final design documents for the project. The project has been broken down into multiple Phases in response to concerns addressed in the environmental study phase. After eighty years of planning, studies and false starts, the project has begun construction with the award of the first contract for the launch box and tunnel boring machine (TBM) excavated tunnels between 92nd Street and 63rd Street in March 2007. The design is well underway for three new stations and the rehabilitation of one station with award of the next contract planned for the second half of 2008.

The paper will give a status report on the design and construction progress and provide information on the successive contracts to be awarded and the schedule for completion. Paper will include a discussion of lessons learned during the initial construction phase and the response as incorporated into the subsequent contract documents.

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SECTION 1 - BACKGROUND

In December 2001, The DMJM Harris*Arup Joint Venture (DHAJV) was awarded a contract for the Conceptual Design and Preliminary Engineering of the Second Avenue Subway for MTA/New York City Transit (NYCT). With an initial contract period of three years to complete the field investigations, support the on-going Environmental Impact Statement development and

perform the preliminary engineering work, it was clear that the staffing of the project would require a mix of various types of professionals and a well defined project management plan and quality assurance system.

After completion of the preliminary engineering, DHA received a notice to proceed with the Final Design of the Phase 1 work in April 2006. The Full Funding Grant Agreement (FFGA) for the complete Phase 1 of the Project was received in November 2007.

1.1 Project Scope

The proposed Second Avenue Subway is a new two-track subway line running from 125th Street and Park Avenue at the north, east along 125th Street to Second Avenue and south along Second Avenue to the Financial District in lower Manhattan. With sixteen new stations and 8.5 miles (13.7 km) of track, the project's estimated cost was \$16 billion in 2004 dollars escalated to the midpoint of construction. The project includes utilization of three existing tunnel segments that were constructed in the 1970s as part of the last attempt to construct the project before unstable financial conditions in New York City forced all construction to be stopped.

The project has been broken into four construction phases to make funding of this mega project more manageable. The initial Phase 1 operating segment includes three new stations (96th, 86th and 72nd Street Stations) with a connection to the existing Broadway line at the 63rd Street Station at Lexington Avenue. Rehabilitation of the 63rd Street Station is also included in the scope of this phase. Subsequent phases extend service north and west to 125th Street (Phase 2), south to Houston Street (Phase 3) and finally to Hanover Square (Phase 4).

The DHAJV proposed alignment is a mix of hard rock TBM tunnel and earth pressure balance/slurry tunnels. The northern limits of the project generally are in deep soil overburden on

rock that will require mixed face drilling capability. The 125th Street Station will be constructed below the existing Lexington Avenue line station and connect via passageways to the Metro-North Commuter Railroad Station at 125th Street. This will give commuters from the suburbs north and east of New York City direct access to the City subway system. The 116th Street Station will be constructed within an existing tunnel sections (Segment 132-13) between 110th and 120th Streets which will require modification to accommodate the wider platforms required by today's standards. The 106th Street Station will connect this existing segment with existing Segment 132-11 between 99th and 105th Streets.

The 96th Street Station is one of the shallowest stations at approximately 42 feet (13 meters) below street level due to the necessity to connect to Segment 132-11. This same tunnel segment will be used for overnight train storage for the Phase 1 initial operating segment. The tunnels south of 96th Street to 63rd Street are deep in rock which will permit use of a main beam hard rock TBM. The stations at 86th and 72nd Street are deep rock caverns which will be excavated using drill and blast construction methods through access shafts to the street.

The central portion of the alignment (Phase 3) between 63rd Street and 6th Street is predominantly Manhattan Schist with some areas of low rock cover that may make a double-shielded mixed face TBM necessary for some segments. New stations will be constructed at 54th, 42nd, 34th, 23rd, 14th and Houston Streets. Stations in this area range between 80 and 90 feet (24 and 27 meters) in depth below ground surface.

The southern portion below the Houston Street Station (Phase 4) is predominantly soft ground tunneling with high water table requiring an Earth Pressure Balance (EPB) machine or slurry machine. The exception is the Hanover Square Station which is a deep rock station in anticipa-

tion of a future extension under the East River to Brooklyn. In addition to Hanover Square, there are stations at Grand Street, Chatham Square and Seaport.

1.2 The Team

DMJM Harris has been a leader in one-of-a-kind tunnel projects introducing innovation in design and procurement practices in the United States for several years with projects such as the Tren Urbano and Baltimore Metro systems in our list of successes. For a project the size and importance of Second Avenue, it was determined that a team which included international tunnel expertise would bring added benefit to the project. The resulting two-thirds/one-third joint venture with Ove Arup combined the strong national experience of DMJM Harris with the European and Asian tunneling experience of Arup. At the peak of the design activity there were almost 300 people in the project office.

SECTION 2 - THE DESIGN PARAMETERS

2.1 Design Philosophy

The design of the Second Avenue Subway by contract was to employ 21st Century technology - a difficult challenge when faced with trying to integrate a new service into one that has existed since the first portion of the New York City system began operation in 1904. Most of the equipment and infrastructure within the NYCT system is original and has been maintained in the same manner since inaugural service began.

2.1.1. Topographic Survey/GIS Database

As part of the early field investigation work a complete topographic survey was performed of the entire corridor from 125th Street to the Hanover Square area. Because there were still several alignments being considered in the southern portion of the alignment, survey of each of the proposed alignments was included. Initial efforts included a complete low-altitude aerial survey us-

ing helicopters to insure the maximum level of detail for design purposes. Areas along the right-of-way that were obscured by the canyon effect of tall buildings or blocked by bridges or other obstructions were resurveyed using ground survey. The entire alignment was tied into the New York State Coordinate System using horizontal and vertical control points.

In areas where existing tunnels passed above or below the alignment, the crossing tunnels were surveyed using laser survey methods. In some locations where clearances between structures were critical such as at the Long Island Rail Road East River Tunnels, laser scans were conducted in one tube of each set of tunnels. Similarly, the existing bell-mouth at the NYCT 63rd Street Tunnel was also laser surveyed to ensure that the connection alignment met the criteria for horizontal and vertical curvature.

As the design progressed and potential entrance and ancillary building locations were identified, data on the existing buildings impacted was collected including building owner, tax record identification, photos of all properties on both sides of Second Avenue, building plans and façade maintenance records.

All this information, including the survey data, has been incorporated into the project Second Avenue Subway Geographical Information System (GIS). Data will be added to the system as the design progresses including the geotechnical information from boring logs, test pit logs, and metes and bounds surveys of the potential easements.

2.1.2 Geotechnical Investigation

DHAJV commenced the geotechnical investigation in March 2002. Using information available from the 1970's Deleuw Cather design, boring locations were selected based on gaps or areas of special concern. Since the alignment proposed by DHAJV was significantly deeper than the

original cut and cover alignment developed in the 1970's, borings were drilled to approximately 125 feet (38 m) depth below the street surface. Approximately 600 historical borings were collected from various sources including the previous design effort, various project files of team members, utility projects, and adjacent private developments. Over 400 new borings were taken along the Second Avenue Subway corridor to determine and/or verify ground conditions. In addition, over 200 environmental borings were taken in the soil overburden at locations where present or prior activities may have resulted in hazardous or industrial soil contamination.

The soil investigation included not only the basic soil sampling and rock coring for laboratory testing and classification, but also oriented core drilling, cone penetrometer tests, geophysical surveys of bore holes, installation of monitoring wells and vibrating wire piezometers, observation wells, packer testing in bedrock, cross-hole seismic testing, seismic refraction testing and in-situ stress testing.

Based on the data collected, a series of reports were prepared cataloguing the results and findings for each of the areas of the project. Contract documents for each major construction contract include a Geotechnical Data Report, a Geotechnical Interpretive Report and a Geotechnical Baseline Report.

2.1.3 Structural design

Design of the tunnels required that the tunnels withstand dead and live loads associated with overburden, hydrostatic pressure, and seismic loading.

Because Second Avenue is lined with various types of buildings including four and five story brick buildings and high-rise structures, control of settlement caused by excavation techniques including groundwater maintenance was a major concern. Cut and cover construction areas are

designed using secant pile or slurry walls to prevent large quantities of water from entering the excavation. Groundwater drawdown limits were established for pumping systems that might be used to control inflow.

2.2 Tunnel and station cavern lining systems

One of the criteria that had been established by NYCT required that the tunnels be watertight with no visible leakage below the springline of the tunnel and only minor wet spots would be permitted above the springline. As part of the Study Phase of SAS, various liner systems were evaluated for possible use in the project. These included cast-in-place, sprayed and precast concrete. Mix designs were also studied that resisted fire and heat loads, reduced permeability, used steel fiber reinforcement in lieu of rebar cages, and used recycle materials such as fly ash to increase the durability of the concrete.

Ground stabilization and protection of existing structures was another key design issue. DHAJV undertook a survey of existing buildings adjacent to the alignment to identify the foundation types used for different classes of buildings to establish temporary support requirements. Where entrances or ancillary facilities such as ventilation buildings or emergency exits affect existing buildings more detailed surveys and non-destructive testing was undertaken as part of the early Final Design effort.

Using several modeling methods to analyze the forces acting on the station cavern lining systems, the DHAJV team identified five rock conditions with typical reinforcement and lining systems for each type. Having established a maximum settlement criterion of 0.75" (19 mm), each lining system was put through a test using UDEC evaluation. In areas where there were historic or sensitive structures, this settlement criterion was only 0.5" (12.7 mm). It is also proposed that during the construction of the cut and cover sections, a geologist would be present to observe

the work and determine whether field support conditions are within the parameters defined as a result of the modeling exercise.

At the current time, the design of the final liner for the caverns and drill and blast tunnel sections assumes that the initial lining contributes nothing to the strength of the final liner i.e. the final liner is designed to handle 100% of the loading. DHA JV will further investigate use of a contributory allowance for the initial lining in supporting the final lining during the finale design preparations.

2.2.1 Crossover Caverns

At several locations spaced approximately eight minutes running time apart, crossovers were required to permit trains to be switched from one track to another in the event of train failure or other activity affecting track availability. Wherever possible these crossovers were located adjacent to a station to take advantage of the larger construction areas. Some of these crossovers are located deep in the Manhattan bedrock and will be excavated using drill and blast construction methods. One such crossover, located south of the 72nd Street Station, will accommodate four mainline tracks as they diverge and split off from the through 2nd Avenue "T" tracks to the 63rd Street tunnel. As a standard practice, all rock station caverns are designed as drained structures.

Crossovers are also provided at both ends of the 125th Street Station, west of Park Avenue and under 3rd Avenue, south of 96th Street, north and south of 72nd Street, south of 42nd Street, south of 23rd Street, north of Houston Street and north of Hanover Square. Many of these crossover locations will serve as construction staging areas once construction starts. For example, the crossover south of 96th Street is being used as the launch pit for the first tunnel contract. The crossover north of Houston will be the launch pit for the TBM run north to 34th Street and the

crossover at 3rd Avenue and 125th Street will be used to launch TBMs east towards 2nd Avenue and west to the tail tracks near Fifth Avenue.

2.2.2 Station Design

Most of the New York City Transit system was constructed by private rail companies at the beginning of the 20th Century. The system celebrated its 100th Anniversary in 2004. Because many of the lines and stations were constructed before established building codes, present station platforms are often very narrow and poorly served by street access. In fact, it wasn't until the early 1990's that NYCT became subject to the New York State Building Code as a subsidiary of the Metropolitan Transportation Authority, a state Agency.

The new stations incorporate all requirements of state building code and applicable fire and safety guidelines including NFPA 130. As a result, station platforms, which are designed to provide a Level of Service 'C', are considerably wider than their predecessors, typically more than 28 feet (8.5 meters) wide. Platform vertical circulation units include a mixture of stairs, escalators and elevators designed to permit clearing of loaded subway platform within 45 seconds of the train's departure.

Ancillary space requirements have increased significantly due to requirements to provide smoke evacuation and ventilation systems throughout the station areas. In most cases, the ancillary spaces are provided underground as part of the station structure. While this was not always possible, it helped to minimize the number of properties that had to be acquired at street level. Typical underground structures are approximately 700 to 1300 feet (214 to 396 meters) long with the platform area accounting for 615 feet (187 meters) of it. All of the stations utilize center island platforms for easy transfer and consolidation of vertical circulation units. The 125th Street

Station will have three tracks in order to meet specific operational requirements. At this stations, the third track will be served by separately accessed side platforms.

SECTION 3 - DEALING WITH THIRD PARTY INTERFACES

3.1 Utility Companies

As one can imagine, for a project the size of the Second Avenue Subway, excavation in the streets of Manhattan means major impacts on existing utility lines. In an attempt to keep utility owners focused on the needs of the project, a Utility Task Force was created in July 2002. The Task Force met on a monthly basis and included all the major utility owners including Con Ed for electric, steam and gas, Verizon and Empire City Subway (ECS) for telephones and communications and New York City Department of Environmental Protection (NYCDEP) for water and sewer. While there are several smaller users in the communications ductbanks, ECS and Con Ed worked directly with their tenants for those services.

The project's Utility Group collected existing utility plans and the location of all active services was plotted on the topographic maps. Field verification of locations was performed through field survey and test pit excavation.

3.2 NYC Department of Transportation (NYCDOT)

On the island of Manhattan where traffic on a good day travels at a crawl, the project's construction will be taking half of the lanes of Second Avenue out of service. This was the primary problem we faced when trying to develop maintenance and protection of traffic (MPT) plans for the project.

Second Avenue presently has six lanes of traffic during the morning rush period. After the rush, the western-most lane becomes a bus lane and parking is allowed on the east side leaving four moving lanes of traffic. In early meetings with NYCDOT, DHAJV was informed that four lanes of traffic would have to be kept open at all times. The right-of-way for Second Avenue is 100 feet (30 meters) wide building line to building line. A tunneling construction operation requires lay-down and staging area at the surface level to support deliveries and muck removal. The solution requires that the present sidewalks, which are slightly more than 20 feet (6 meters) wide, be reduced to approximately 7 or 8 feet (2 meters) to permit the driving lanes to be shifted onto the present sidewalk locations to create a new traffic lane.

NYCDOT has issued stipulations for the traffic management during construction and these stipulations have been incorporated into the Terms and Conditions of each of the contract packages.

SECTION 4 - CURRENT STATUS

4.1 Contract No. 1 – TBM Launch Box and Tunnels

In April 2007, NYCT awarded a contract for \$337 Million to S3 Tunnel Constructors, a tri-venture comprised of the firms of Skanska USA Civil, Schiavone and Shea, for the construction of the TBM launch box and the mining of the TBM tunnels from 92nd Street to 63rd Street. The Launch Box will ultimately become the southern half of the 96th Street Station. Work commenced almost immediately with the removal of the street trees, furniture, building awnings, canopies, etc. in order to implement the traffic diversions needed to start work. Utility relocation is complete on the west side of Second Avenue within the limits of the contract between 91st and 95th Street. Utility relocation is currently underway on the east side and will be completed in July 2008. At that point, work on the secant pile and slurry walls forming the perimeter of the launch box will begin on the west side of Second Avenue. The TBM is expected to arrive on site in June 2009.

4.2 Contract 2A – 96th Street Station Heavy Civil/Structural

At the time of this writing, contract documents for the 96th Street Station Heavy Civil/Structural package are out to bid. This contract completes the northern half of the 96th Street Station box and rehabilitates the existing tunnels section between 99th and 105th Street. This contract also includes the demolition of an existing building at the site of a new fan plant and construction of the underground structure for three entrances and two ancillary buildings. Similar to the launch box contract, this contract includes relocation of all the existing utilities that presently lie within the limits of the box, excavation of the area between the slurry walls and placement of a precast concrete roadway deck over the excavation. This contract is expected to be awarded in September 2008.

4.3 Follow-on Contracts

The original contract packaging scheme for Phase 1 of the Second Avenue Subway consisted of six construction contracts. The first contract was the tunnel boring contract which is dis-

cussed above. Each of the four stations (96th, 86th, 72nd and 63rd Street) were to be single contracts for all work at each of the locations. The sixth contract would have been the track, signals, communications and traction power work. New York City currently has five major tunneling projects underway: Long Island Rail Road East Side Access, the No. 7 line Extension to the Javitts Center, Water Tunnel No. 3, South Ferry Station and the Trans Hudson Express Tunnel between New Jersey and Penn Station (otherwise known as Access to the Region's Core or ARC). Due to the limited resources available to progress all of these major tunnel projects concurrently, MTA Capital Construction determined that the size of the construction packages should be reduced to the more manageable \$250 to \$400 million dollar contract limit in hopes of increasing competitive pricing and reducing the risk of single or no-bid solicitations. This provided some relief to the contracting pool since the construction bond market was getting tighter with the changing economic conditions. There are now a total of thirteen contracts proposed as shown in the comparison in Table 1 below.

The next contract to be released for procurement will be the advance utility relocation and cut and cover shaft work for the 86th Street Station. This contract will prepare two shaft areas at 86th and 83rd Streets from which the future heavy civil/structural contractor can begin the cavern excavation. This contract was expected to be advertised in September 2008 with an award in Spring 2009.

SECTION 5 – LESSONS LEARNED

5.1 Agency/Third Party Coordination

As discussed in the previous paragraphs, one of the strengths of the design team was the early involvement of the utility owners, elected officials and applicable agencies responsible for the general public's well being.

The key to success with third party interests is to communicate early and often with them to make sure they are well informed and can respond intelligently and correctly to questions they might receive from the public. The worst situation is to have people giving out incorrect or out-dated information to the public. When properly informed, the number of people who have opportunities to interface with constituents magnifies the public relations coverage.

5.2 Early Peer Reviews

The value of peer reviews cannot be overstated. If the budget permits multiple peer reviews for your project, it is suggested that reviews be held at the conceptual design stage in discipline specific sessions. At the Conceptual Design stage, second opinions or design changes are relatively inexpensive to incorporate into the documents. Waiting until the end of the Preliminary Design is not advisable because the level of detail and coordination required will be significantly more costly to correct.

5.3 On-Board Reviews

One of the major contributors to the successful design of Second Avenue was the process of conducting on-board reviews on a regular basis through the working groups. This process allowed the DHAJV team to meet with the owner's design, construction management and operations teams to review each critical design decision and document the decisions that were made at these meetings. Once an item had been reviewed and discussed it was at the working group meetings, position papers were prepared and presented to the Technical Advisory Committee for signature. These signed documents are kept in the document control system for record purposes.

SECTION 6 - ACKNOWLEDGEMENTS

I'd like to thank Anil Parikh, the MTACC Program Manager of the Second Avenue Subway Project for his review and support. The Team has worked together cooperatively for six years without major distractions to ensure that this project is progressed in the most cost effective way within the very challenging schedule.

TABLE 1 – CONTRACT PACKAGING PLAN	
Original Contract Package	Proposed Contract Packaging
Contract No. 1 – Launch Box, TBM Tunnels 92 nd Street to 63 rd Street, and Access shafts at 69 th and 72 nd Street	No Change
Contract 2 – 96 th Street Station	Contract 2A – Heavy Civil Structural Works for 96 th Street Station
	Contract 2B – Mechanical Electrical and Plumbing Work
	Contract 2C – Architectural and Structural Finishes
Contract 3 – 63 rd Street Station Rehabilitation	No Change
Contract 4 – 72 nd Street Station	Contract 4A – Advance Utility Relocation and Building Demolition Contract for Entrance #1 and Ancillary #2
	Contract 4B – Heavy Civil/Structural works including Mining and Lining of Cavern
	4C – MEP and Finishes Contract
Contract 5 – 86 th Street Station Construction	Contract 5A – Advance Utility Relocation and Cut and Cover Shaft Construction
	Contract 5B – Heavy Civil/Structural Works including Mining and Lining of Cavern
	Contract 5C – MEP and Finishes Contract
Contract 6 – Systems Contract Including Track, Signals, Electric Traction and Communications	Contract 6A – Communications
	Contract 6B – Track, Signals and Electric Traction Work