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New York City Transit's pilot project for communications-based train control

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Abstract

New York City Transit (NYCT) is one of the oldest, largest and most complex subway systems in the world, and as part of its ongoing modernisation program, NYCT plans to upgrade its signal system from fixed block/wayside signals to communications-based train control (CBTC) technology. CBTC technology was assessed as the best solution for NYCT's needs, offering enhanced performance, lowest life-cycle costs and minimum operational disruption during implementation.

Given the size of the NYCT subway system, the transition to CBTC technology must be implemented in stages over a number of years. The implementation strategy is further complicated by the fact that the NYCT track is a complex rail network of highly interoperable lines. As a consequence, CBTC-equipped trains that normally run on one line must also be capable of operating over other CBTC-equipped lines modernised both prior to and subsequent to equipping of the cars. A key element of NYCT's CBTC implementation strategy, therefore, is to establish interoperability interface standards that will permit independent procurement of wayside and trainborne CBTC equipment.

NYCT's 20-year implementation strategy for CBTC is based on a procurement approach that uses the Canarsie line as the Pilot project for proving the new technology and developing interoperability standards. This paper summarizes the status of this ambitious signal modernisation program.

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1 Background

The New York City Transit (NYCT) subway system is one of the largest and most complex transit systems in the world. It consists of over 1,100 km of track and its 25 subway lines provide service to 469 stations, carrying over 4 million passengers per day with a fleet of over 6,000 revenue and non-revenue rail vehicles.

Almost half of the existing signal system is more than 75 years old and as part of its ongoing subway modernisation program, NYCT plans to upgrade its signal system from fixed block, wayside signals/trip stop technology to state-of-the-art communications-based train control (CBTC) technology, utilising two-way digital RF communications between intelligent trains, and a network of distributed wayside zone controllers.

NYCT's decision to adopt CBTC technology was made after an extensive technology assessment which concluded that CBTC was the best solution for NYCT's needs, offering shorter headways, greater operational flexibility, enhanced safety, lower life-cycle cost and minimum operational disruption during implementation. The technology assessment also recommended a 20-year implementation strategy, and proposed a procurement approach using NYCT's Canarsie line as the Pilot project for proving the new technology (Ghaly [1]).

2 Communications based train control

The basic characteristics of a CBTC system include (Rumsey [2]):

- Determination of train location, to a high degree of precision, independent of track circuits.
- A geographically continuous train-to-wayside and wayside-to-train RF data communications network to permit the transfer of significantly more control and status information than is possible with conventional systems.
- Wayside and trainborne vital processors to process the train status and control data and provide continuous automatic train protection (ATP), automatic train operation (ATO) and automatic train supervision (ATS) functions.

With a CBTC system, train location is known with a much higher resolution than with track circuit-based signalling systems. This allows trains to operate safely at much shorter headways and permits system operations to recover more rapidly in the event of a disturbance; all of which provides more regular and improved passenger service. Shorter headway translates directly to increased

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line capacity, and CBTC systems can therefore support significant and measurable increases in ridership without the major investment associated with the construction of new transit lines.

CBTC systems not only provide shorter headways but also lower maintenance costs (resulting from less trackside equipment and improved diagnostics), greater operational flexibility, enhanced safety (due to continuous overspeed protection), smoother and more predictable operation, and improved reliability and availability (thorough redundant/fault tolerant designs). CBTC systems also provide a foundation for further integration of transit system control functions. For example, the wayside-to-train data communications link can also be used to support other functions, such as triggering passenger information displays and automatic announcements on board trains, and downloading train health monitoring information to wayside maintenance centres.

3 NYCT's CBTC implementation strategy

Given the size of the NYCT subway system, the transition to CBTC technology must be implemented in stages over a number of years. The implementation strategy is further complicated by the fact that the NYCT track is a complex rail network of highly interoperable lines. This interoperability permits a high degree of operational flexibility and system-wide fault tolerance and NYCT desires to retain this flexibility where feasible as it transitions to CBTC technology. As a consequence, CBTC-equipped trains that normally run on one line must also be capable of operating over other CBTC-equipped lines modernised both prior to and subsequent to equipping of the cars.

A key element of NYCT's CBTC implementation strategy, therefore, is to establish interoperability interface standards that will permit independent procurement of wayside and trainborne CBTC equipment.

The Canarsie line will be the first location at NYCT to be equipped with CBTC technology. The Canarsie Line is basically a two-track line, 18 km in length, with 24 stations and 7 interlockings. Approximately two thirds of the line is underground with 23 track km in tunnel, and 2 track km in under river tubes. On the remaining one third of the line, approximately 5 track km is at grade, and approximately 8 track km is on elevated structure. The existing signal system on the Canarsie line is traditional fixed-block technology with wayside equipment. Original equipment that is still in operation on the line was installed in 1926.

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4 Canarsie line procurement strategy

A unique aspect of the Canarsie line project is the three-phase procurement process that is being used to select the new signal system and develop interoperability interface standards (Rumsey [3]).

4.1 Phase I: CBTC demonstration test program

As a first step in the procurement process, a Request for Proposals (RFP) for the Canarsie line project was issued to the industry in October 1997. Technical proposals were received from six suppliers in February 1998.

In July 1998, based on an evaluation of these proposals, NYCT short listing three suppliers (Alcatel, Alstom and Siemens (Matra)) to demonstrate their CBTC systems on a designated NYCT test track (Phase I). Each of the short listed suppliers was compensated a fixed sum (US$1.1 million) for participating in the demonstration tests.

NYCT staff completed the installation of the suppliers' trainborne and wayside equipment on the NYCT test track in December 1998, within five months of the Phase I contract awards, using installation designs prepared by each of the suppliers. Extensive installation checkout testing, data radio propagation testing, and CBTC integration testing was completed during January and February 1999. Formal demonstration tests commenced in March 1999, running for approximately 5 months to July 1999.

To ensure a fair comparison between the competing CBTC systems, all suppliers demonstrated against a common test plan. The Phase I demonstration tests were divided into seven test segments. The first six test segments were dedicated to demonstrations of data radio communications; train location and speed measurement; ATP functions; failure management functions; other miscellaneous operational functions; and maintainability/diagnostic functions. The final test segment was reserved for optional tests selected by the individual suppliers.

The suppliers were provided an opportunity to dry-run planned tests of a segment prior to formal demonstration for NYCT. Each test segment had to be completed in the agreed time allotted and in general, no carry-over of time from one test segment to another was permitted. With NYCT approval, however, test elements that were not completed within the time allocated for a given test segment, could be included as one of the supplier's optional tests in the final test segment.

To ensure the successful completion of the demonstration test program, on schedule and without protests, NYCT appointed a full-time Test Director with the authority to manage the day-to-day test planning, to foster consensus among

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the test witnesses, and to maintain cooperation between suppliers in a competitive procurement environment.

4.2 Phase II: CBTC system implementation

Based on the results of the demonstration test program, NYCT's evaluation of the suppliers' technical and management proposals, formal software and system safety audits, references from other transit properties, consideration of the price proposals, and negotiations with each of the suppliers on risk mitigation, the CBTC system best suited for NYCT's requirements was then selected for installation on the Canarsie Line (Phase II). A contract for this design/supply/install/test/commission contract, totalling US$133 million, was awarded to a joint venture of Siemens (Matra)/Union Switch & Signal/RWKS Comstock in December, 1999.

The central, wayside and trainborne CBTC equipment to be supplied by Siemens (Matra) for the Canarsie line is based on the system currently in operation on the RATP Meteor line in Paris. Union Switch & Signal will supply all of the conventional signalling equipment required for the Canarsie line project, including relay-based interlockings, signals, automatic trip stops, track circuits, switch machines, etc. RWKS Comstock will be responsible for system installation.

The Canarsie Line CBTC system will provide continuous, two-way digital RF communications between intelligent trains using highly reliable (redundant) trainborne equipment and a network of highly reliable (redundant) vital distributed zone controllers installed in relay rooms. Fault tolerant equipment design will ensure that operation of the system will continue in the presence of any single point failure.

CBTC zone controller equipment and associated CBTC trainborne equipment will provide Automatic Train Protection (ATP) functions associated with safe train separation assurance and overspeed protection. Separate CBTC zone control equipment and interlocking equipment will be provided with typically one (redundant) zone controller at each set of interlocking control equipment. The primary ATP functions of the CBTC system include:

- Determination of train location by the trainborne CBTC equipment.
- Communication of train location information from the trainborne CBTC equipment to the wayside CBTC equipment (zone controllers) over an RF train-to-wayside data communications link.
- Determination of movement authority limit information for each CBTC-equipped train, by the wayside zone controllers, based on train derived location information and inputs from wayside interlockings.

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- Communication of the movement authority information from the zone controllers to trainborne equipment over an RF wayside-to-train data communication link.
- Determination and enforcement of the safe speed/distance profile by the trainnborne CBTC equipment.

The CBTC train-to-wayside RF data communication network will be integral to the CBTC system design and will consist of wayside and trainborne transceivers, antennas, data communications controllers and fiber optic interconnections. For the Canarsie line, the train-to-wayside datalink will use 2.4 GHz spread spectrum radios. The CBTC train-to-wayside datalink will support all required ATP, ATO and ATS functions and will provide continuous geographic coverage throughout the Canarsie line in tunnels, tubes, cuts, on elevated structures, and at grade. The CBTC datalink will support bi-directional data transfer with sufficiently low latency to support the defined performance requirements. The datalink will include a protocol structure to support safe, timely, and secure delivery of train control messages, and will include provisions to overcome unintentional and intentional electromagnetic interference.

The fleet of revenue trains for the Canarsie line will be composed of 184 new technology trains. Maximum operating consists will be 8 cars formed of two 4-car units. There will be an operating cab at each end of a 4-car unit with driver controls and displays. CBTC equipped trains will be capable of operating in various modes, depending on whether the train is operating in CBTC territory or non-CBTC territory, and depending on the operational status of the trainborne and/or wayside CBTC equipment.

CBTC equipment located at NYCT's new Control Centre will provide Automatic Train Supervision (ATS) functions for the Canarsie line. The CBTC-ATS system will track and display the locations, identities, schedule and other pertinent data for all equipped and unequipped trains operating on the Canarsie line. The CBTC-ATS system will support computer-aided automatic routing and dispatching functions, and will monitor, report on, and control the performance of all trains in relation to variance from schedule and/or headway. Schedule/headway control will be accomplished through dwell time control (including train holds) and control of train performance, within ATP profile limits.

To provide for mixed mode operations, that is, operation of unequipped trains in CBTC territory under wayside signal protection, the CBTC system will be integrated with an Auxiliary Wayside System (AWS). The AWS will consist of "conventional" wayside signal system components including track circuits, color light signals, and tripstops. CBTC and AWS will be treated as

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one integrated train control system, thereby eliminating or reducing conflict and arbitration between CBTC and AWS functionality during failed or degraded states. The CBTC system will be designed such that CBTC equipment failure rates will be sufficiently low to preclude the need for a back-up system and to minimize train operations under AWS. However, the AWS installation for operation of unequipped trains will have the additional benefit of providing signalling protection during the infrequent CBTC system failures.

4.3 Phase III: CBTC interoperability demonstrations

As part of the Phase II contract, the "lead" supplier will also provide detailed interoperability interface specifications for the "standard" (Canarsie line) system so that two "follower" suppliers can develop compatible systems and demonstrate the interoperability of their systems with the "lead" supplier's system (Phase III).

The Phase III program will run concurrently with the Phase II program with both the Phase II and Phase III programs being completed by December 2004.

With this approach, after the successful completion of the Canarsie line project, NYCT will have 3 qualified suppliers of trainborne CBTC equipment and 3 qualified suppliers of wayside CBTC equipment. For future car procurements, trainborne CBTC equipment will typically be included in the carbuilder's scope of supply (using the pre-qualified CBTC suppliers). CBTC wayside equipment will be procured on a line segment by line segment basis under the signal modernisation program, and interoperability will be assured through the interface specifications developed during the Canarsie line project.

Phase III is not a competitive process and the objective of NYCT and all of the suppliers will be to work cooperatively to successfully develop and validate interoperability interface specifications.

While not a competitive process, Phase III is also <u>not</u> a consensus standard development effort, since the system architecture, functional allocations, interfaces and protocols will be defined by the Phase II ("lead" supplier's) CBTC system. Input from the "followers" will however be critical to ensure that the interoperability interface specifications submitted by the "lead" supplier are complete and unambiguous.

To offset the costs associated with participation in the Phase III program, NYCT is prepared to offer each "follower" a fixed sum of the order of US$10-13 million. Negotiations are currently taking place with Alcatel and Alstom and award of Phase III contracts is scheduled for the summer of 2000.

The "lead" supplier will submit a preliminary version of the interoperability interface specifications after completion of the Phase II preliminary design phase in April 2001. This preliminary version of the specifications will be a

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complete document, but will be subject to change as the "lead" supplier's design is completed with the final version of the interoperability interface specifications available in February 2003. The interoperability interface specifications will include the following:

- System Requirements Specification (summarizes operating, performance and functional requirements of the complete CBTC system).
- System Description (describes the system architecture and principles of operation for the selected Phase II CBTC system).
- Allocation of Functions (describes the allocation of the system requirements to each subsystem (include safety targets for vital functions) for the selected Phase II system).
- Interoperability Interface Requirements (lists all system interfaces for interoperability and for each interface defines general, functional, performance and physical characteristics. This includes items such as control flows, data elements, protocols and message descriptions).
- Interoperability Interface testing (for each interface, defines the tests that need to be performed to verify interoperability).

The Phase III interoperability interface validation test program will demonstrate, at a minimum, interoperability between:

- The "lead" supplier's wayside CBTC equipment and the "follower" supplier's wayside CBTC equipment (including seamless hand-off of trains and ability to interface with a common CBTC-ATS system).
- The "lead" supplier's wayside CBTC equipment and the "follower" supplier's trainborne CBTC equipment.
- The "lead" supplier's trainborne CBTC equipment and the "follower" supplier's wayside CBTC equipment.
- The "lead" supplier's trainborne CBTC equipment and the "follower" supplier's trainborne CBTC equipment (in multi-unit train).

The minimum criteria to be satisfied in Phase III in order for a supplier to be qualified to bid on future CBTC contracts at NYCT will include the following:

- Successful completion of interoperability demonstration test program verifying the supplier's ability to supply CBTC equipment that complies with the NYCT interoperability interface specifications.
- Ability to supply hardware capable of operating in the NYCT environment.
- Ability to supply software capable of meeting NYCT standards.
- Ability to supply a "safety certified" CBTC subsystem.

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5 Partnering philosophy

To ensure the success of the Canarsie Line project, NYCT has adopted a philosophy of partnering between all project participants. This implementation approach includes partnering internally within NYCT between Engineering, Operations, Maintenance, Car Equipment and Procurement groups; partnering between NYCT and their engineering services consultants, partnering between NYCT and other transit agencies throughout the world who are implementing or planning to implement CBTC systems, and partnering between NYCT and the supply industry developing new technology signal systems to meet the needs of NYCT and other transit agencies.

The successful, on-schedule, completion of Phase I and the selection of a "lead" supplier for Phase II has demonstrated the benefits of the partnering/"no-surprises" philosophy, with an integrated project team clearly focused on the project objectives and schedule, and embracing open and frequent communications with all project participants.

6 Conclusions

New York City Transit's pilot project for communications-based train control continues on schedule with the successful completion of the Phase I demonstration program and award of contract for the Phase II system implementation on the Canarsie line.

The Canarsie line project will establish and validate interoperability interface standards for CBTC technology to permit multiple suppliers to offer compatible and interoperable wayside and trainborne systems. CBTC interoperability standards developed for NYCT may also be applicable to many other North American and international transit properties.

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