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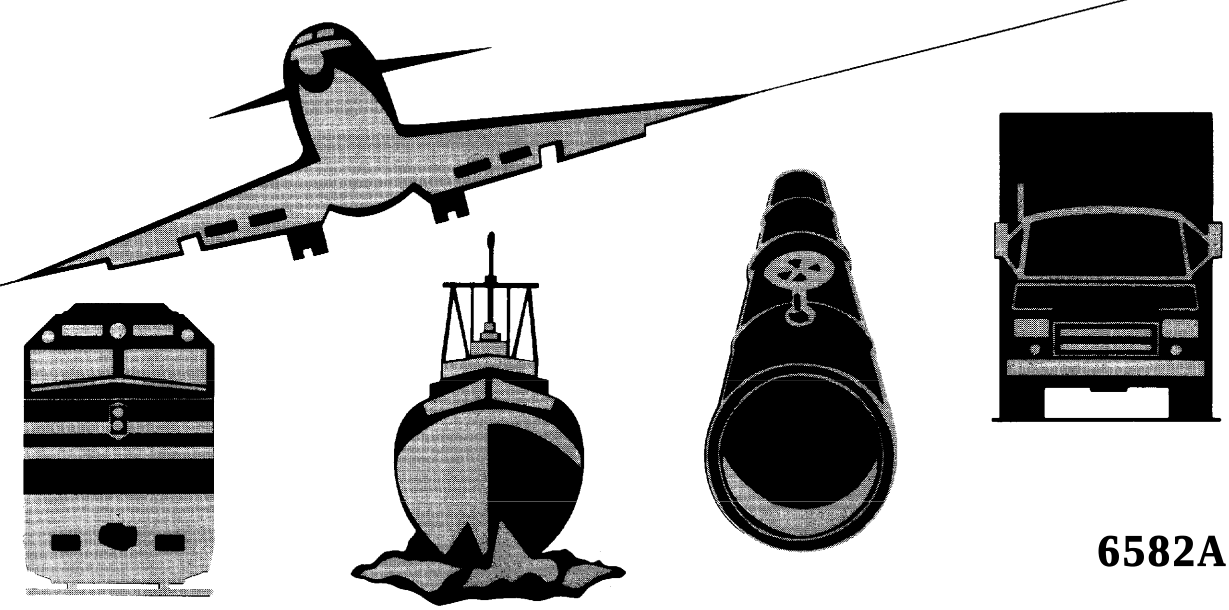
NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C. 20594

RAILROAD ACCIDENT REPORT

COLLISION INVOLVING TWO NEW YORK CITY SUBWAY TRAINS ON THE WILLIAMSBURG BRIDGE IN BROOKLYN, NEW YORK JUNE 5, 1995



6582A

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NTSB/RAR-96/03 **PB96-916303**

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RAILROAD ACCIDENT REPORT

Collision Involving Two New York City Transit Subway Trains on the Williamsburg Bridge in Brooklyn, New York June 5, 1995

Adopted: September 4, 1996
Notation 6582A

Abstract: This report explains the collisions of two New York City Transit subway trains on the Williamsburg Bridge in Brooklyn, New York on June 5, 1995. One person was killed and 69 people were treated at area hospitals for minor injuries sustained in this accident. The total estimated damage exceeded $2.3 million.

From its investigation of this accident, the Safety Board identified the following safety issues: the fatigue of the J train operator, the adequacy of New York City Transit oversight programs, notably in the area of communications rules compliance, and the adequacy of spacing between signals.

As a result of its investigation of this accident, the Safety Board made recommendations to the Federal Transit Administration, the American Public Transit Association, and the New York City Transit.

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EXECUTIVE SUMMARY

About 6:12 a.m. on June 5, 1995, a New York City Transit (NYCT) southbound J subway train collided with the rear car of a stopped NYCT M subway train. The collision occurred on the Williamsburg Bridge about 16 feet south of signal J2-125 on the Brooklyn Borough side of the Bridge. The operator of the J train was fatally injured in the collision. Sixty-nine people, including two emergency responders, were treated at area hospitals for serious or minor injuries.

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the J train operator to comply with the stop indication because he was asleep and the failure of the train to stop within the block because of inadequate braking distance between signals on the Williamsburg Bridge. Contributing to the accident were the New York City Transit's inadequate measures for ensuring employee compliance with proper radio procedures.

The major safety issues discussed in this report are the fatigue of the J train operator, the adequacy of NYCT oversight programs, notably in the area of communications rules compliance, and the adequacy of spacing between signals. The report also discusses positive train separation, crashworthiness, and oversight by the New York State Public Transportation Safety Board.

As a result of its investigation of this accident, the Safety Board makes recommendations to the Federal Transit Administration, the American Public Transit Association, and the New York City Transit.

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INVESTIGATION

The Accident

The operator and the conductor of the New York City Transit (NYCT) southbound 531 J subway train[1] went on duty at 11:38 p.m.[2] on June 4, 1995. They were scheduled to make three round trips from the Jamaica Center station to Broad Street station in Manhattan (see figure 1). The J train conductor testified that the first two trips were made in the "proper manner," and that "nothing [was] out of the ordinary." He stated that they departed Jamaica Center station for the third trip on time at 5:31 a.m., that the train operator seemed to be operating the train in the usual manner and at the proper speeds, and that all the station stops were routine. He said that as they pulled out of Kosciusko Street station, they had to stop and wait at the junction point to allow an M train to pass in front of them.

The eight-car M train, with a crew comprising a train operator and a conductor, had departed the Metropolitan Avenue station on time at 5:48 a.m. The M train operator said that he made several station stops without incident. He stated that as he departed Marcy Avenue (the last station before the Williamsburg Bridge), he was following a work train, which was clearly visible from a distance of about 30 car lengths. He also stated that he had no problem seeing the signals at that time of morning. He said that as he approached the bridge, he was "creeping" behind the work train, having to stop at red signals a couple of times before he stopped his train at signal J2-120 (figure 2). The M train conductor later testified, "Normally we would not stop in the morning there [on the bridge] .... There's usually no trains in front of us." The M train operator did not radio the command center dispatcher to report any of the stops, as he was

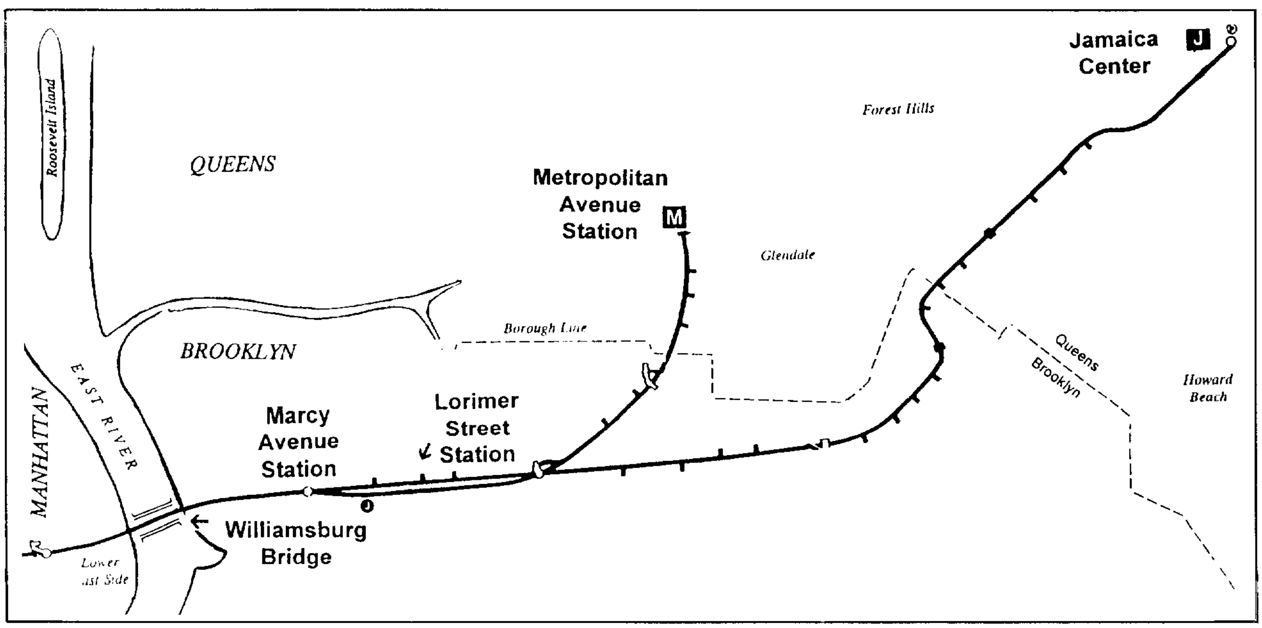

Figure 1 — Routes of the J train and the M train.

[1] All NYCT trains are designated by the clock time that they leave their originating station and by their route line. For ease of reference, this report refers to the two trains only by their route designation.

[2] All times in this report are eastern daylight time.

required to do by the NYCT operating rulebook. (Additional information about required operating procedures appears in the *Operations* section of this report.) According to witnesses, when the M train stopped at signal J2-120, the conductor made a general announcement: "Ladies and gentlemen, we are being held here at a red signal. As soon as the signal is clear, we shall be moving shortly."

Meanwhile, the J train had stopped at Lorimer Street station to pick up several passengers, including an off-duty NYCT train operator who was en route to work. He stated that as he boarded, he and the J train operator waved to one another. He said that the J train operator seemed awake and alert. The off-duty operator stated that he took a seat near the front of the lead car, diagonally across from the train operator's compartment.

After the J train left Marcy Avenue station about 6:10 a.m., the J train conductor said that he went to the conductor's compartment in the third car to relax. The off-duty train operator riding on the J train stated that when they departed Marcy Avenue station, the J train operator "handled it [the train] like anybody else would have done," accelerating "... all the way because you got eight cars and you are going uphill."[3]

Meanwhile, after the conductor's announcement on board the M train, an NYCT road car inspector traveling to work had stood up in preparation to debark at the next stop. He was in the next to last car of the M train. He said that he happened to glance through the storm door into the last car and "saw the [J] train coming to hit us." He testified that because he was a car away, he couldn't see the J train operator or estimate the train's speed, but that "he was coming pretty quick ... at least 30 miles an hour."

About the same time, the off-duty operator riding the J train said that he was reading a newspaper when he heard the chow sound[4] and that "within 3 seconds," the J train struck the rear of the M train. The J train conductor also stated that he heard a chow "a matter of seconds" before impact. He said that he couldn't really estimate the length of time between the train brakes going into emergency and the collision because his "mind wasn't engaged on what was exactly happening." He explained that he had had a hectic Sunday, and had managed to get "only a couple hours sleep" before reporting to work. He stated, "I was feeling like I will be glad when the night is over....You know, anyone who's worked midnights knows there's certain times of the night you feel a little fatigue."

None of the 16 cars from the two trains derailed from the impact, but the lead car of the J train penetrated the rear car of the M train resulting in extensive damage to these two cars (figure 3) and the fatal injury of the J train operator. When the off-duty train operator on the J train noticed smoke coming from the front end, he instructed other passengers to run from the car and then assisted in evacuating people from the train. Within 5 minutes of the collision, a bystander called the New York Police Department (NYPD) 911 dispatcher, reporting that a train collision had occurred on the bridge. The NYPD immediately notified the Fire Department of New York (FDNY) and dispatched police and rescue personnel to the scene. Initial emergency responders arrived on scene within 5 minutes of the 911 notification call. They arranged to have a transit bus and 47 ambulances transport 55 injured passengers and crewmembers to 11 area hospitals. Several individuals with minor injuries either were treated and released at the scene or sought treatment elsewhere. Additional information about the response effort appears in the *Survival Factors* section of this report.

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[3] Before this accident, the NYCT had no speed restriction on the bridge approach.

[4] A blow of air sound that occurs when a train goes into emergency braking.

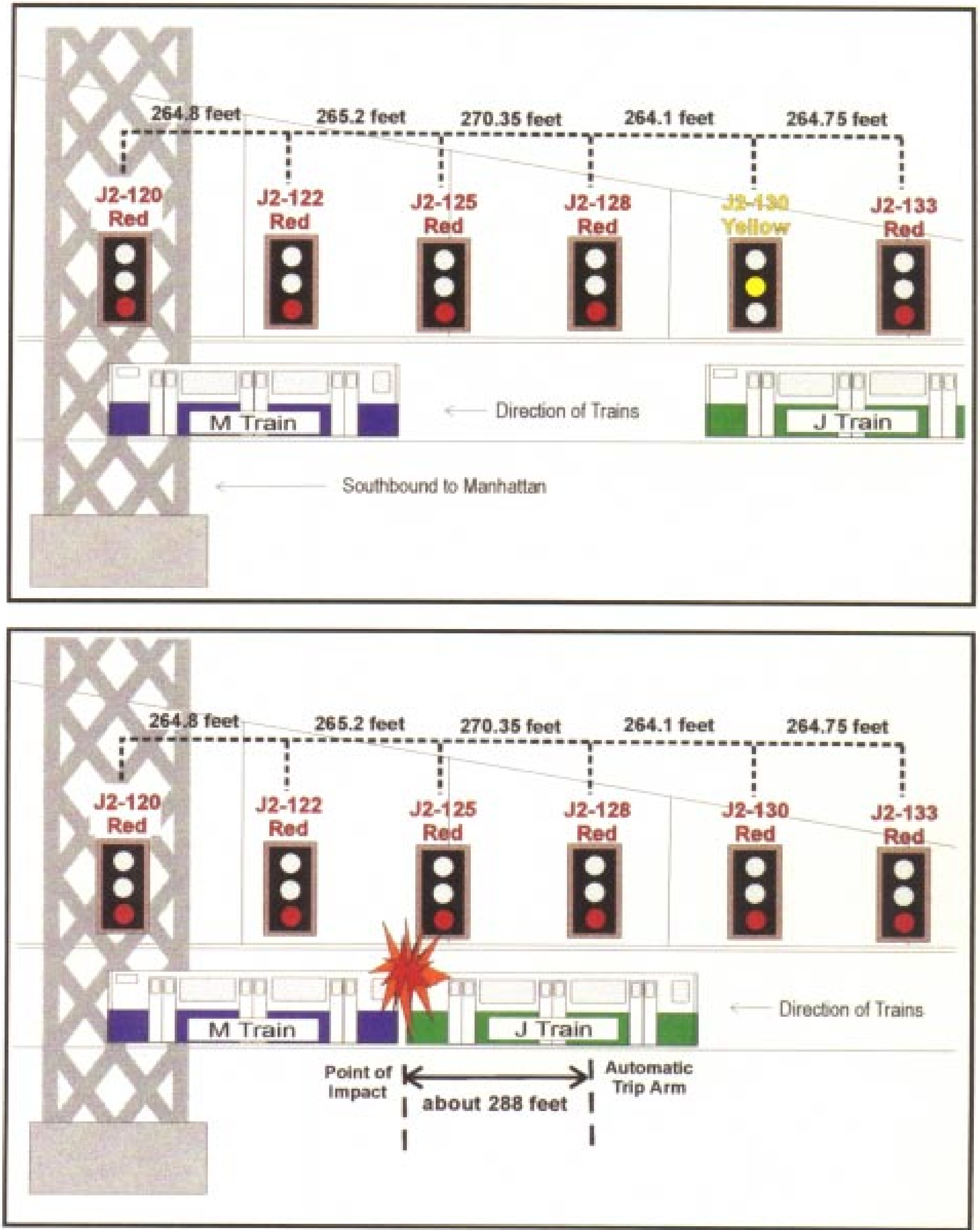


Figure 2 — (Top) The M train was stopped at Signal J2-120 when the J train proceeded past a yellow caution light at Signal J2-130 traveling about 34-36 mph. (Bottom) Although the automatic trip arm at red Signal J2-128 properly activated the emergency braking of the J train, it failed to stop within the 270-foot-long block and struck the rear of the M train, which was 16 feet beyond Signal J2-125.

Figure 3 — The accident site.

Injuries

Table 1 is based on the injury criteria of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes. The number of reported injuries reflects only the crewmembers of the two trains and those individuals transported to a medical facility. The chart does not reflect the passengers on board the two trains who elected to be treated on scene by medics rather than be taken to a hospital. Emergency responders estimated that about 100 passengers were on board the two trains when the accident occurred.

Damages

Damages were limited to the rear four cars of the M train and all eight cars of the J train. The signal system and the track were not affected. The NYCT officials estimated the cost of the damaged train equipment and site cleanup exceeded $2.3 million dollars. A detailed description of damages appears in the *Wreckage* section of this report.

Personnel Information

Safety Board investigators reviewed the professional background and the experience of all four crewmembers involved in this accident.

Table 1 — Injuries Resulting from the Williamsburg Bridge Accident.

Injury Type	J Train Crew	M Train Crew	Passengers	Other*	Total
Fatal	1	0	0	0	1
Serious	0	0	2	0	2
Minor	0	0	62	2	64
None**	1	2	0	0	3
Total	**2**	**2**	**64**	**2**	**70**

*Two police officers sustained minor injuries while assisting accident victims at the site.

**This category contains only the crewmembers for the two trains.

Information about the M train crewmembers and the conductor of the J train appears in appendix B. The J train operator's professional background, experience, work/rest activities, and medical factors are described below.

Background — The J train operator, age 46, was hired on October 17, 1977, as a train cleaner. He was promoted to train operator on June 21, 1981, and became an operator on the J line in May 1989. He received refresher training on April 9, 1991, and substance-abuse awareness training on November 23, 1994. On May 2, 1995, he was given an Operating Employee Evaluation; no items were rated as "unacceptable."

The J train operator worked the 11:30 p.m. to 7:30 a.m. "pick," so called because employees request to work a given shift. On this midnight pick, his regular days off (RDOs) were Saturday and Sunday, meaning he was off duty from 7:30 a.m. on Friday until about 11:30 p.m. on Sunday. The Safety Board reconstructed a 72-hour history of the J train operator's activities before the accident (table 2).

Life Style and Routine — Co-workers described the J train operator as mild-mannered, quiet, and professional. He had been on the same work schedule for several years and routinely reported to work early to prepare for his duties. He ate his meals at home about the same time daily. He neither drank alcoholic or caffeinated beverages nor smoked. He exercised 4 days a week, usually Monday through Thursday. Family members and co-workers described him as physically fit and health conscious.

Disciplinary Actions — Personnel records show that the most recent and serious disciplinary action against the J train operator was a 2-day suspension on January 23-24, 1992, that stemmed from a December 3, 1991, incident during which he stopped his train short of a station, leaving two cars outside of the station limits. He also failed to give the conductor the proper signal, which resulted in her opening the doors improperly. As a result of these rules violations, the train operator was required to take 1 day of retraining on March 12, 1992, in the following subject areas: Track, Switches, and Signals; Yard and Road; Trouble Shooting; and Emergencies. He returned to service on March 13, 1992.

Table 2 — J Train Operator's 72-Hour History

Date/Time	Status/Activity*	Rest (hrs)
Friday, June 2		
Before 0730	On duty	
0730 - 1300	Off duty; did personal errands.	
1300 - 1730	Napped and awoke before 1730. (Time that he began nap is not known.)	0 to 4.5
1900	Walked dog.	
2000	Had dinner.	
2230/2300	Went to bed between 2230 and 2300.	
Saturday, June 3		
0500/0530	Awoke between 0500 and 0530.	7.0
0530-0800	Did personal chores.	
0800	Had breakfast.	
0800 - 1100	Did personal chores.	
1100 - 1400	Had lunch and napped until 1400. (Time that he began nap is unknown.)	0 to 2.5
1400 - 2100	Did some chores, including yard work.	
2100	Had dinner.	
2200/2230	Went to bed between 2200 and 2300.	
Sunday, June 4		
--- 0600	Awoke	7 to 8.0
0600 - 0900	Did personal chores.	
0900	Had breakfast	
1000	Did yard work.	
1130 - 1500	Napped.	3.5
1500	Showered, shaved, and dressed.	
1700-2030	Had dinner and napped until 2030. (Time that he began nap is unknown.)	0 to 3.5
2030	Walked dog and left for work.	
2330	Reported to work.	
Monday, June 5		
0612	Accident occurs.	
Rest in the 24 hours before accident: 3.5 to 6.5 hrs		
Time on duty before accident: 6 hrs 42 min		

*Information provided by family and co-workers.

The J train operator's personnel file also contains a reprimand for sleeping in a darkened room while he was on duty during a midnight shift on January 18, 1989.

Medical Factors — According to his medical records and to testimony from his family, the J train operator had no major ailments and was in good health. His last company medical examination was on July 22, 1994, during which he was found medically qualified to perform full work. He was required to wear prescription glasses. On the night of the accident, he had been seen wearing his glasses. He was not taking any prescription or non-prescription medication at the time of the accident. He had not complained of muscle aches or chest pain and had not missed work because of illness since March 1995, when he was home for 8 days with the flu. His family members stated that he did not have trouble falling asleep or sleeping until his usual waking time. Another NYCT train operator who had worked on and off with him for 2 years stated that the J train operator would get sleepy between 3 a.m. and 6 a.m., and that he, "like many other train operators, had problems at night trying to stay awake." She said that on one occasion he mentioned that he had "barely made it this trip" because he had trouble staying awake.

Train Information

Description of Cars — Each of the trains in this accident had eight cars that operated in "married" pairs joined by a semi-permanent link. The J train had all R-40 series cars; the M train had all R-42 series cars. These cars are powered by a traction motor on each axle. A truck-mounted electrical pickup shoe receives current from a third rail. All of the cars were built by the St. Louis Car Company in the late 1960s and overhauled by contractors in the late 1980s. Table 3 shows the attributes common to these cars.

Braking Systems — As part of its investigation of this accident, the Safety Board held a public hearing on November 29-30, 1995, in New York City. In testimony, an NYCT official described the braking system of the R-40 cars. Like most subway cars, the R-40 units have two braking modes, service and emergency. The service brake is used in regular operation to regulate the speed of and stop the train. Service braking is a blend of dynamic (electrical) and pneumatic braking. When the train operator places the brake valve handle between the number 2 and 3 positions (see figure 4), the dynamic and pneumatic braking modes are mixed to provide a constant deceleration rate to slow or stop the train. The

Table 3 — Consists of the Accident Vehicles

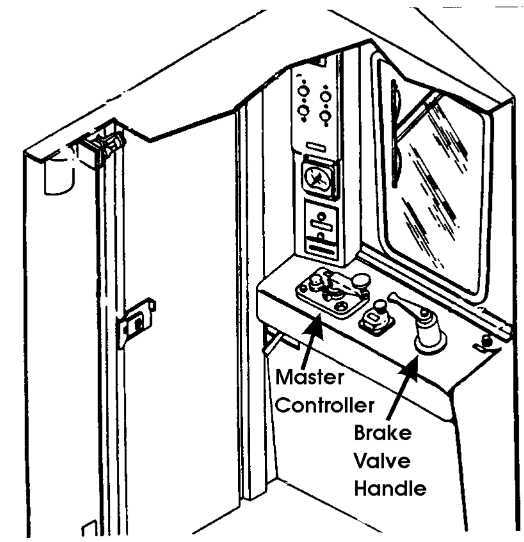
Consist Position	J Train All R-40 Series		M Train All R-42 Series		Common Attributes of R-40 and R-42 Series Cars
1	4461	A	4622	B	4-axle, stainless steel cars. Odd-numbered units are "A cars" and even-numbered units are "B cars" In a married pair, one car is equipped with an air compressor and the other car has the batteries and converter. Weight: (pounds) R-40 A car - 74,043 R-40 B car - 74,204 R-42 A car - 74,344 R-42 B car - 74,433 Dimensions: 60 feet 6 inches long by 10 feet wide. Seating capacity: 44
2	4460	B	4623	A	
3	4489	A	4611	A	
4	4488	B	4610	B	
5	4536	B	4587	A	
6	4537	A	4586	B	
7	4453	A	4665	A	
8	4452	B	4664	B	

dynamic mode deactivates and the pneumatic brake completely controls the braking when train speed is between 7-10 mph, depending on the current build up in the brake circuit.

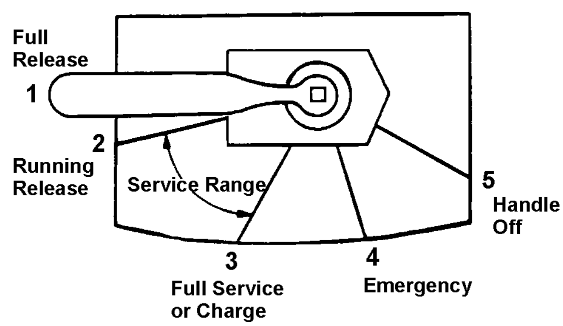
The emergency braking system is totally pneumatic and is initiated whenever pressure in the brake pipe is reduced at a given rate. Emergency braking can be activated in four ways. The train operator can move the brake valve handle to the number 4 (emergency) position. In the event that the train operator releases the controller handle, it will rise to the deadman position, which automatically activates the emergency braking system.

Emergency braking can be activated by pulling an emergency cord, which is located in each cab and at the end of each car in the passenger compartment. The NYCT system also has an external means of activating a train's emergency braking system, the in-track automatic stop arm, which is mounted on the track bed next to the rail, parallel to each wayside signal. When a signal displays a red, or stop, indication, its companion in-track automatic stop arm rises to an elevated position. Should a train pass a red wayside signal, the raised stop arm will strike the lead car's "trip cock," a metal lever that activates the emergency braking system. More information about the automatic stop arm appears in the *Signal* section of this report.

Braking System Components — To accommodate variations in passenger load yet stop with predictable consistency, a transit car braking system is equipped with a load sensor and a variable load valve. The load sensor is an electro-pneumatic device that detects the amount of (passenger) load compression on the suspension system and then adjusts the variable load valve to attain a brake cylinder pressure that corresponds to the measured load. The load sensor is integrated with the dynamic brake; as such, the sensor controls the degree of braking effort during service braking.



The master controller in the operator's cab is the device that the operator uses to control the speed and direction of the train. An operator must keep the master controller handle in the normal or depressed position at all times while the train is moving unless the brake valve handle has been put into the full service position.



The controller contains a pneumatic valve (not shown) that releases air if the spring-loaded valve raises to the deadman position, which initiates emergency braking.

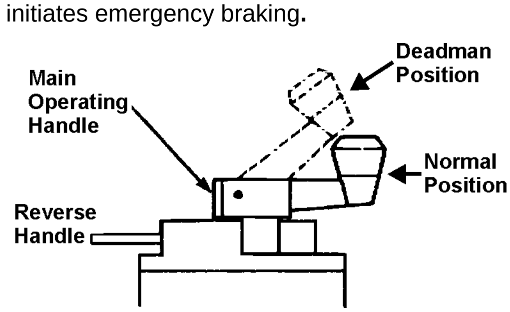


Figure 4 — (Top to bottom) Cutaway of the train operator's cab, overhead view of the brake valve handle, and a side view of the master controller.

The R-40 cars were originally equipped with cast-iron brake shoes. When the NYCT had the cars rebuilt during the 1980s, the brake shoes were changed to a composition type, which required the NYCT to modify or replace many brake system components, including the variable load valve. The NYCT officials stated that the brake cylinder pressure was adjusted so that the car would have maximum braking capability, yet its wheels would still rotate rather than slide until the train stopped.[5] The load sensor and the variable load system have four basic reference settings. The lowest load setting is for empty cars, that is, cars having no load; the second load setting is for cars having a given number of primarily seated passengers per square foot; the third setting is for cars having a given number of seated and standing passengers per square foot; and the highest setting is for cars having a maximum passenger load. Before the Williamsburg Bridge accident, the NYCT had set the load sensor at 15 psi +/- 2 for empty cars and 80 psi +/- 2 for fully-loaded cars, which resulted in brake cylinder pressures of 27 psi +/- 2 and 37 psi +/- 3, respectively.

Braking Parameters — The NYCT has 23 different types of cars in its fleet. An NYCT official testified that the brake system performance requirements are the same for all cars. For service braking, the NYCT requires a deceleration rate of 3.0 mph per second (3 mphps). For emergency braking, the NYCT requires a deceleration rate of 3 mphps. Stopping distance requirements depend upon a train's speed and the track profile. He said that all car types should have the same braking performance during service or emergency braking.

The transit company official testified that when the NYCT has identified braking problems in certain models, the company has taken corrective measures to bring the cars within standard. During single-speed (30 mph) brake tests performed in 1993 of 18 car types, 3 models stopped within the required braking distance of 250 feet. The stopping distance for the other 15 models ranged from 253 feet for the R-62 cars to 353 feet for the R-42 cars. The NYCT determined that the R-42 cars failing to stop within the braking parameters were those that were equipped with the New York Air Brake system originally installed when the cars were built. The NYCT subsequently identified and removed 110 cars with original braking equipment from the 392 R-42 cars in its fleet and adjusted the variable load valves of the cars so that they would stop within the NYCT braking parameters. The braking distance of R-40 cars in the 1993 tests was 276 feet.

Modifications to Cars — After this accident, the NYCT conducted its own brake tests on Williamsburg Bridge using a train consisting of R-40 cars fitted with Datron EEP-2 instruments. The NYCT tests showed that the train attained an average maximum speed of 36.1 mph at signal J2-128, which was higher than the maximum attainable speed of 27.9 mph on which the signal spacing was designed.[6] The NYCT subsequently began modifying the R-40 cars and other types of cars in an effort to ensure that its vehicles would be able to stop within acceptable braking parameters. The modifications included retarding the acceleration performance and increasing the brake cylinder pressures. The transit company also adopted a single emergency braking standard in 1995. A more complete discussion of the cars' acceleration performance appears in the *Signal* section of this report.

Adjustments made to the cars' braking pressure varied with the type of car. In the case of the R-40 cars, the pressure was increased to 30 psi +/- 2 for empty cars and 40 psi +/- 3 for fully-loaded cars. Officials stated that about 67 percent of the cars in the NYCT fleet

[5] Sliding creates flat areas on the wheel, which reduce wheel life, provide a rough ride, and cause vibration and impact that can damage the car.

[6] The spacing between signals on the Williamsburg Bridge was based on the R-9 car, an earlier class of car that is no longer in the NYCT fleet. Additional information about signal design is in the *Signal* portion of this report.

the fleet should be in compliance by December 1997. They said that changing the brake cylinder pressure probably will result in increased maintenance costs because the wheels likely will develop flat areas from sliding during emergency braking. They stated that because emergency stopping is an exceptional condition, the company is willing to incur the potential cost to ensure trains can stop within the NYCT braking parameters.

Speedometers — No Federal, State, or local regulations require NYCT trains to be equipped with event recorders or speedometers. Neither train involved in the accident was equipped with an event recording device or a speedometer.

As a result of its investigation of a March 1989 accident in which an NYCT subway train rear-ended an NYCT revenue train stopped at the 103rd Street station, the Safety Board found that the failure of the NYCT to furnish its operators with a reasonable means for determining speed contributed, in part, to the severity of the accident.[7] On March 21, 1990, the Board made the following recommendation to the NYCT:

R-90-02

> Provide speed indicators on each car in service on the system to allow train operators the ability to properly determine speed.

On June 14, 1990, the NYCT responded that it was evaluating five to seven speedometer systems that could be installed on existing cars and that it planned for the new trains to have speed indicators on all lead cars. On August 13, 1991, the NYCT wrote the Board that by 1991 it would begin installing speed indicators on the control cars in the R-44 fleet and that, after a 1-year evaluation of the R-44 installations, it would install speed indicators in the operating cabs of the other car types. The Safety Board responded on December 24, 1991, that until all control cars or operating cabs of other car types were equipped, the status of the recommendation would remain "Open—Acceptable Response." In a May 14, 1993, letter, the NYCT indicated that installation of speedometers was part of its 1992-1996 capital improvement program. Shortly after the Williamsburg Bridge accident, an NYCT official testified that the NYCT hoped to have speedometers installed on "all but the car type [the Redbird] we will be retiring," or 4,600 of the 5,800 cars in its fleet by the end of 1996, and that new cars being purchased had speedometers and event recorders. In a June 1996 telephone conversation with Safety Board investigators, an NYCT official indicated that because of problems with contractors, only 2,551 cars had thus far been retrofitted with speedometers. He stated that the NYCT expected to have speedometers installed on an additional 1,456 cars by the end of the year. Moreover, as an interim safety measure, the transit company intended to outfit several hundred of the Redbird cars that were not scheduled to be retired for several years.

On-site Equipment Inspection — During its on-scene equipment inspection, the Board's mechanical group examined the power control group box underneath the J train's lead car, 4461. The dial indicator on the power cam shaft was in the No. 20 position, indicating that the propulsion system was in full power when the brakes went into emergency.

Investigators examined the trip cock arm on the No. 1 end of car 4461 and observed a small amount of yellow paint near the end of the arm. They measured the distance of the trip cock arm to the rail and determined that the arm was about 1-1/4 inches above the rail, which was within the NYCT standard. Investigators had the trip cock assembly removed and taken to the NYCT Coney Island Pneumatic Shop, where new and rebuilt trip cocks are qualified

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[7] For additional information, read Railroad Accident Report--*Rear-End Collision of Two New York City Transit Authority Trains, 103rd Street Station, New York, New York, March 10, 1989* (NTSB/RAR-89/02).

on a test rack. The trip cock functioned as designed in a series of tests, including a leakage test and a 45-pound pull test. When testers displaced the valve 18 degrees from vertical in either direction, it activated properly. During visual examination, investigators noted that the trip cock had been rebuilt by a worker with the initials "KE" on the night shift in June 1994.

Track

The collision occurred on the Brooklyn Borough side of the Williamsburg Bridge, a steel beam and girder double tower suspension bridge with open deck frame construction, that spans the East River between Brooklyn and Manhattan. The point of impact was between the Brooklyn (east) tower and a cable anchorage, about 16 feet south of signal J-2 125.

Two parallel tracks are in the center of the bridge: the J1 track is for northbound train movements to Queens; the J2 track is for southbound train movements to Manhattan. Elevated wooden-plank pedestrian walkways are on the outer side of each track, and double-lane roadways are below the walkways. The walkway on the south side had been closed to pedestrian traffic as part of a bridge repair project. The construction did not affect the subway operation or the roadway traffic. At the time of the accident, crewmembers on the repair project were beginning to report to work, but had not begun construction.

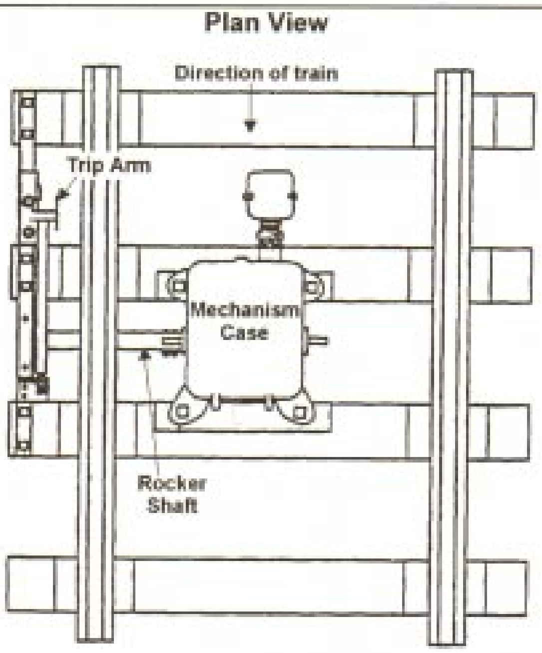
The bridge approach is on tangent (straight) track that ascends 2.75 percent, levels off, ascends again and then decreases 2.25 percent to the point of impact. The rail is 100-pound heat-treated ARA-B steel that was installed in 1984 and that is anchored with base applied rail anchors, using different anchoring patterns for ascending or descending grades. The bridge ties are pressure-treated yellow pine. The tie plates are 14-inch double shouldered and are attached with two rail holding spikes and two plate holding spikes. The NYCT records show that the track had last been inspected on June 4, 1995, by a track walker, who noted no exceptions. The last geometry car was operated through the area on May 24, 1995; the resulting print-out revealed no defects or items below standard. The track meets NYCT MW-1 Track Standards, which are equivalent to Federal Railroad Administration (FRA) Class 4 track maintenance standards.

Signal

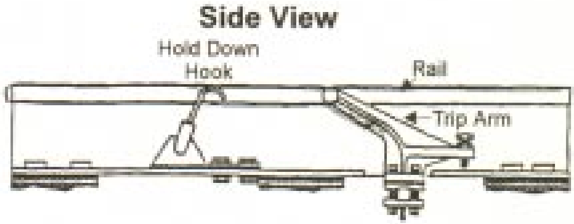
General — The NYCT signal system is an automatic block signal (ABS) system that uses wayside automatic and interlocking colored-light signals controlled by the circuitry in the rail.[8] The wayside light signals are supplemented by automatic stop arms (figure 5).

As designed, the system uses the trains' accelerating and braking characteristics to determine the maximum attainable speed and the "emergency brake stopping distance" at each location. The emergency brake stopping distance is calculated using the actual distance that a train takes to stop on a given grade at a particular speed (the train's brake system performance) and adding a safety margin of about 35 percent to compensate for such factors as third-rail voltage fluctuations and wet rail conditions. Emergency stopping distances determine the minimum length of the signal system "control line," that is, the number of blocks needed to provide a safety margin of at least 35 percent. The number of signals that companies use is determined by the headway, or the amount of time between trains.

[8] A line is divided into track circuits that are separated by small gaps in the rail called insulated joints. A block is the spacing between signals and may consist of one or more track circuits. When a train's wheels pass over an insulated joint, the current is diverted to the train's axle, basically causing a short in the signal circuit. This process, called shunting, affects the signals for three blocks in the line. The signal in the block where the shunt occurs changes to a red aspect; the signal immediately behind the occupied block displays a red aspect; and the signal two blocks back changes to a yellow aspect.



The automatic stop arm has three primary components: a circuit controller, which opens and closes the electrical circuits; a heavy compression spring, which raises the stop arm by pushing it upright; and an induction motor with a gear train, which lowers the stop arm by retracting it down against the spring. Like the aspects of the wayside signals, the electrical current in the track circuitry governs the position of the trip arm. If the energy supply to the motor is interrupted, the spring returns the wayside trip arm to the upright stop position.



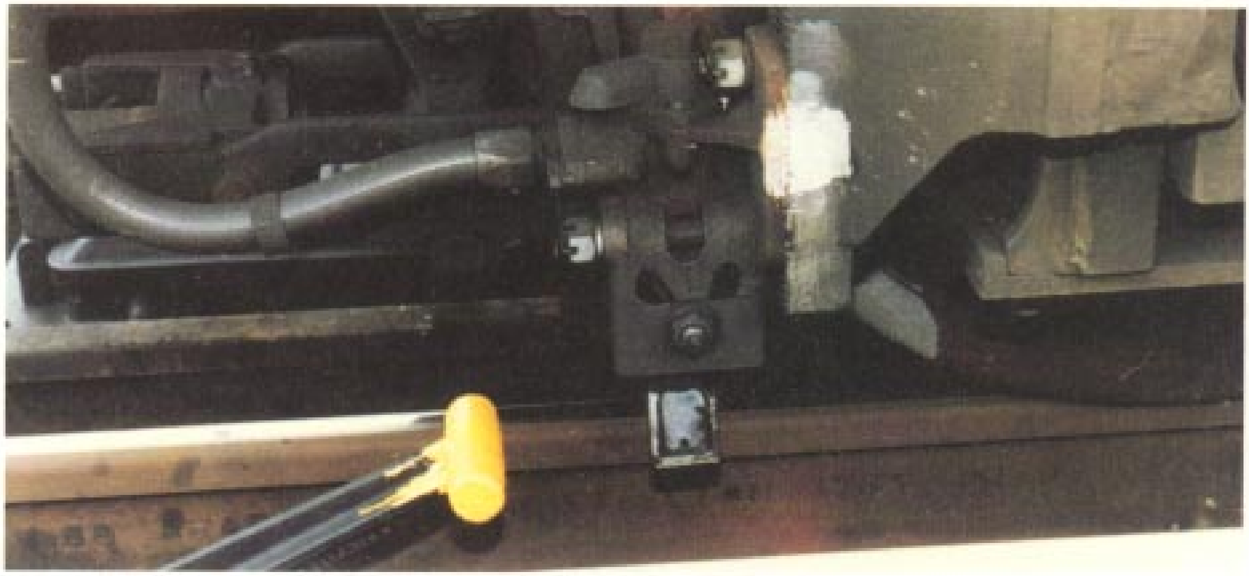


Figure 5 — Top illustrations show plan and side view of a wayside trip arm. Photograph shows a lowered trip arm (painted yellow) in front of a train trip cock.

The NYCT System — Some areas of the NYCT signal system, including Williamsburg Bridge, were installed in 1918. The design of about one-third of the system was based on the acceleration and braking capacity of the R-9 car, which was built before 1948. The R-9 car had two 190-hp motors and an acceleration rate of 1.75 mphps up to 17 mph after which the motor curve governs.[9] About two-thirds of the

[9] As a car accelerates, its traction motor circuits change from series, to series-parallel, to parallel to enable it to operate within its speed range without overloading its electrical equipment. This design feature results in reduced acceleration efficiency at higher speeds.

system is based on the operating capabilities of the R-32 model car, which dates from the mid-1960s. The R-32 car had four 100-hp motors and an acceleration rate of 2.5 mphps up to 17 mph after which the motor curve governs. Newer and rebuilt cars have four 115-hp motors and acceleration rates of 2.5 mphps up to 17 mph. The design of the newer cars provides better braking than the design of older models at speeds governed by the motor curve, that is, speeds exceeding 17 mph, but does not provide better braking at lower speeds. After the Williamsburg Bridge accident, the NYCT began installing a shunt on the motor field winding to retard the acceleration capacity. To date, the transit company has modified the acceleration performance of about two-thirds of its cars; it expects to have its entire 5,800-car fleet modified by December 1996.

The average spacing between signals throughout the NYCT system is about 350 feet; the average spacing between signals on Williamsburg Bridge is 265 feet.

With the exception of station areas, the NYCT generally uses a two-block control line throughout most of its system. Whenever a train enters a block, the light aspect of the signal at the rear of that block changes from green or yellow to red and the stop arm at that signal remains down to allow the entire length of the train to pass into the block. Once the train has passed into the block, the stop arm at the signal one block to the rear rises to the upright position. The signal of the block to the rear is already red, and its trip arm is in the upright position because it is the block that the train previously occupied. In most instances, the signal for the block after the control line displays a yellow aspect, meaning the train operator is to *proceed with caution, be prepared to stop.*[10] The automatic stop arm for a block in which the signal displays a caution aspect is in the lowered position. Transit officials stated that the NYCT varies the control line, or the number of red signals and yellow signals, depending on the distances between signals. An official indicated that after the Williamsburg Bridge accident, the NYCT will extend the control line in areas where the acceleration and braking modifications to the cars do not provide an adequate safety margin.

The NYCT also provides overlaps of the control lines in station areas. The overlap portion is not a full block but usually ends at a cut section beyond the station. According to NYCT officials, this design generally provides sufficient distance for emergency braking plus a safety margin of 35 percent for trains traveling at a speed of 15 mph, which is the speed for leaving a station required by the NYCT operating manual at Rule 39 (i). The signal design at stations does not provide the distance needed for emergency braking by a train traveling at maximum speed.

An NYCT official testified that, given the performance of the accident vehicle, the 270.35 feet of spacing between signals J2-128 and J2-125 did not provide a sufficient emergency braking distance in a worst-case scenario, which is maximum attainable speed.[11] He stated that the operation of the trains in response to signals "relies heavily upon the train operators complying with the aspects displayed." At a June 21, 1995, hearing conducted by the New York City Council's Committee on Transportation, another NYCT official testified, "New York City Transit has never said that it has a fail-safe (signal) system .... We depend on safe operation. When that occurs, we have a superior safety record."

Before the Williamsburg Bridge accident, the NYCT had recognized that areas in its signal system did not provide sufficient braking distance and had contracted two companies to

[10] Rule 59 (b) of the *Rules and Regulations Governing Employees Engaged in the Operation of the New York City Transit System* (Revised 1992).

[11] The R-40 car is capable of speeds up to 55 mph. The spacing between signals J2-128 and J2-125 is based on the original R-9 car performance. The R-9 car could attain a maximum speed of 27.9 mph at signal J2-128, which would have required 196 feet for emergency stopping.

determine the scope of the problem. Toronto Transit Consultants noted in a study done in 1993 that older areas of the signal system did not comply with the NYCT's design standards. The NYCT addressed the deficiency in its signal system by contracting an engineering firm, Parsons Brinkerhoff, to perform a more detailed examination of sites on the NYCT system. Parsons Brinkerhoff examined 8,257 mainline signals and other signals governing mainline train movements. In the first phase of its signal analysis, Parsons Brinkerhoff found that 51 percent of the signals between stations had no margin of safety based on the braking capability of cars before the NYCT began modifying its vehicles. The NYCT then asked Parsons Brinkerhoff to review the signal safety margins based on modified car performance and the new 1995 braking standard. The contractor completed its analysis of a section of the Queens Line and found that of the 276 signals between stations, 209 had no margin of safety based on the pre-1995 braking and acceleration tests and that all had some margin of safety based on modified car performance and the 1995 braking standard. Based on the Queens Line findings, NYCT officials estimate that the car performance modifications result in fewer than 500 signals between stations not having a safety margin of 35 percent. Of these 500, about 200 signals between stations have a safety margin of less than 25 percent. The NYCT officials stated that the transit company intends to address each of these signals within 3 to 5 years through a combination of in-house signal modifications and signal modernization contracts. The signals will be modified in priority order beginning with those that have less than 100 percent of the required emergency braking distance. In the case of Williamsburg Bridge, the NYCT has posted a 15 mph speed limit on the approach until the signals can be modified.

Long-range Improvements — Before this accident, the NYCT had contracted De Leuw, Cather & Company to identify appropriate technology for the transit company to use in modernizing its signal system. In October 1995, the contractor completed The New Technology Signal System (NTSS) Study, which reviews and compares the performance, safety, reliability, maintainability, and cost of the following signal technologies:

- Modern fixed-block with wayside signals;
- Modern fixed-block with cab signal control;
- Communications-based train control system; and
- Overlay type communications-based train control system.

The study found that a communications-based train control system best met the NYCT's requirements, was the most cost effective, and met industry standards. In a communications-based signaling system, digital components installed on the train and on the wayside transmit and receive signals that are processed by a computer, which automatically regulates the speed of the vehicle, thereby controlling the separation between trains. The systems also record and provide information on train locations, movement authorities, train speed, track conditions, route integrity, work blocks, system health, and other factors that affect the safety of operations. The study concluded that, should the NYCT implement such a system, the number of collisions and other incidents attributable to improper train control and non-mechanical failures would decrease.

According to NYCT officials, the company will be piloting a communications-based control system using two four-car test trains on a 22-mile section of the Canarsie Line. They stated that they are currently working with a design consultant to develop a specification package. Officials indicated that they hope to award a contract in 1998 and expect to have the pilot project in service by 2003. They estimate that installation of computer-based signaling on the entire NYCT system will cost $3.6 billion and take about 50 years.

Operations Information

General — The NYCT system has 25 lines identified by either a letter or number designation. The NYCT data for 1994 shows that total annual ridership exceeded 1.8 billion. An average of 3.4 million passengers rode on week days and half that number on Saturdays and Sundays. The total number of train trips in 1994 was more than 2.2 million; the daily number of train trips averaged 6,568. Each passenger train has a two-person crew of an operator and a conductor. The NYCT has 2,841 train operators and 2,408 conductors.

Operating Procedures — The NYCT operating manual mentioned earlier is provided to all NYCT employees in the form of a hand-size (5 ½-inch-by-7 ½-inch) loose-leaf binder. Rule 40 (m), which is about red automatic signals, is shown in figure 6.

Changes and updates to the operating manual are in the form of letter-sized bulletins that are provided to each employee and are posted on boards at stations. Further, operators are given 15 minutes at the beginning of their work shift to review the information. On March 4, 1993, the NYCT issued Bulletin No. 17:93, changing Rule 40 (M) to clarify the text regarding notifying the command center:

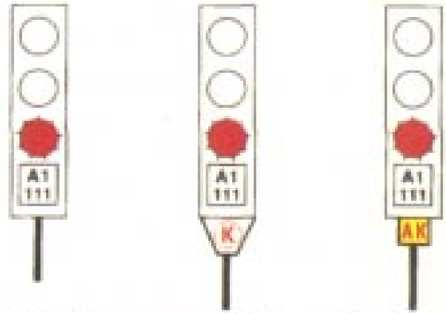
> The Train Operator must call the Command Center Desk Superintendent immediately via radio. If Command Center does not acknowledge the transmission and there is no train visible ahead, he/she must wait two (2) minutes before using the wayside telephone. If after ten (10) minutes and there is a train visible ahead and Command Center still has not acknowledged the radio transmission, the Train Operator must then use the nearest wayside telephone.[12]

After this accident, Safety Board investigators interviewed several train operators and

[12] A photocopy of the bulletin appears in appendix C.

RED AUTOMATIC SIGNALS

(m) A Train Operator must STOP for a RED Automatic Signal.



He/she must stop fifteen (15) feet short of the signal, or at the yellow joint marker plate on the contact rail protection board. He/she must NOT MOVE until the light turns to YELLOW or GREEN, UNLESS:

1. The signal has an "AK" sign; or

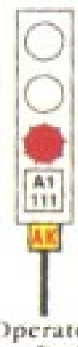
2. The signal is on a storage track or in a yard; or

3. An employee whom the Train Operator KNOWS is an authorized

page break

RTO or Electrical (Signal) employee gives a signal to go ahead which the Train Operator KNOWS is meant for him/her; or

4. The Train Operator calls the Command Center Desk Superintendent by radio and is told to proceed with RESTRICTED SPEED AND EXTREME CAUTION.



The Train Operator must call the Command Center Desk Superintendent immediately via radio. If there is no train visible ahead he/she must wait two (2) minutes. If after ten (10) minutes he/she must proceed to the nearest blue light location or station and use the telephone.

Figure 6 — Photocopies of pages from NYCT employee operating manual.

dispatchers to determine how they interpreted the communications procedures contained in the NYCT operating rules. One operator said that he understood it to mean that upon stopping at a red signal, he had to call the command center after waiting 2 minutes if no train was visible in front of him; however, if a train was visible in front of him, he was required to call the command center after waiting 5 minutes. Another train operator believed that when he came to a red signal, he had to call the command center immediately if he did not see a train in front of him and had to call after 2 minutes if he did see a train. A dispatcher said that train operators should call "right away" when they are stopped at a red signal; however, another dispatcher stated that train operators were required to call the command center immediately if they did not see a train in front of them and after 2 minutes if they did see a train. An October 12, 1995, report on the Williamsburg Bridge accident prepared by the New York City Council's Committee on Transportation[13] found that few of the operators interviewed had ever contacted the command center except in cases of emergencies.

Operational and Efficiency Testing — The NYCT has no formal written efficiency testing program; however, it does periodically perform unannounced checks of its operating personnel for competency and for compliance with operating rules and speed restrictions.

The NYCT uses *The Operating Employee Evaluation Check List*, commonly called the B-Form, to record the competency of train operators and conductors (see appendix D). A train service supervisor completes the report, rating the employee in elements ranging from uniform appearance to overall operation. Before this accident, the B-Form contained 17 elements for conductors and 19 elements for train operators. An employee's competency in each of the elements was rated *Good*, *Acceptable*, or *Unacceptable*. The overall rating that an employee received was recorded in the NYCT computer data base. Before the Williamsburg Bridge accident, the NYCT had 104 train service supervisors to oversee more than 5,200 operating employees. Since the accident, the company has increased the number of train service supervisors to 156.

Before the Williamsburg Bridge accident, the NYCT conducted on-board surveillance checks of train operators for operating rules compliance twice a year. After the accident, the transit company increased the number of on-board surveillance checks to three times a year.

As a result of its investigation of the 103rd Street station accident in 1989, the Safety Board identified the need for speed compliance checks and issued the following safety recommendation to the NYCT:

> R-90-4
>
> Conduct random testing, using radar guns, of train speed, with special emphasis given to those locations where speed restrictions are in effect.

The NYCT concurred with the recommendation, stating that it already regularly monitored train operator compliance with posted speed limits, but that "manpower permitting," it would "intensify ... efforts to ensure that speed restrictions are strictly obeyed." On December 21, 1990, the Safety Board classified Safety Recommendation R-90-4 "Closed — Acceptable Action."

An company official testified that before the Williamsburg accident, the NYCT had conducted speed compliance checks in known problem areas or in response to a complaint. Since the accident, the NYCT has increased the number of speed checks "dramatically," which has resulted in a reduction in violations. In September 1995, the NYCT conducted 669 speed checks and identified 17 violations; in October 1995, it conducted about 900 speed checks and identified 6 violations. He said that the NYCT conducted most of the tests in areas where it

[13] *The Williamsburg Bridge Collision: Findings and Recommendations*, New York City Council, October 1995.

has the greatest risk. He explained that the NYCT does not maintain records of all train operator efficiency tests; it keeps files only on those who fail the tests. Reviewers advise employees only when they have failed a test; they do not tell them when they have passed a test.

The NYCT official testified that the company's Rapid Transit Operations (RTO) and its Department of Electrical Services are developing an efficiency testing program that will feature operating scenarios to which the train operator must respond correctly.

Fitness-for-duty Programs — Federal regulations require that transit companies have drug testing programs and alcohol misuse policies for employees. All covered employees are required to receive at least 60 minutes of training about the effects and symptoms of drug use; supervisors receive an additional 60 minutes of training that focuses on identifying symptoms of alcohol use. Federal regulations do not require that transit companies develop fatigue educational programs or incorporate fatigue awareness in employee training.

The NYCT requires its train dispatchers to evaluate crewmembers' fitness for duty by observing such factors as general appearance, uniforms, mood, and timeliness when reporting to duty. Dispatchers are to remove from service any crewmember judged not to be in fit condition and are to report the employee's removal to the command center.

A dispatcher and an assistant dispatcher who had observed the J train operator on the morning of the accident stated that they did not note anything unusual about his behavior while he was waiting at the station for his next trip. Each of the dispatchers had taken NYCT's 2-day training class on determining fitness for duty about 3 years before this accident; neither dispatcher had received follow-up training.

According to NYCT officials, the intent of the transit company's fitness-for-duty program is to identify employees under the influence of alcohol or controlled substances. In August 1995, the NYCT completed a fatigue study that resulted in the company initiating some policy changes. The Department of Subways has implemented a maximum 16-hour workday,[14] a requirement that each employee must be off duty 8 hours between workdays, and a requirement that each employee must have at least 1 regular day off per pay period. The NYCT has also developed a 5 minute video, *Safe Train Operation*, that discusses safe operating practices for train operators. Additionally, NYCT is investigating the development of a fatigue-awareness program and the feasibility of addressing fatigue in the fitness-for-duty evaluations. Officials stated that the completion date for these programs has not been determined.

Meteorological Information

Witnesses stated that the weather was clear and sunny and that the temperature was 75^0 F at the time of the accident.

Medical and Pathological

The City Medical Examiner of the City of New York performed an autopsy on the J train operator on June 5, 1995, and determined that the cause of death was fractures and visceral lacerations resulting from blunt impacts to the head, torso, and extremities. Toxicological analyses of the train operator's blood, urine, and vitreous humor were negative for drugs and alcohol.

Survival Factors

Emergency Response — At 6:17 a.m., the police 911 dispatcher received a telephone call from a person stating that a train collision had occurred on Williamsburg Bridge. The dispatcher notified the FDNY at 6:17 a.m., which immediately dispatched four engines, two ladder trucks, and one rescue unit from its

[14] The department reportedly is considering implementing a maximum 14-hour workday.

269 Henry Street station, which was about a half mile from the scene. The units arrived at the scene at 6:22 a.m., and the battalion chief had established a command post by 6:34 a.m. Fire department officials reported no difficulties in responding to the scene.

The first life-support ambulance had arrived at the accident site and had established a triage by 6:26 a.m. The Emergency Medical Service (EMS) Command Post was established at 6:33 a.m. near the incident site. The EMS officials reported encountering no difficulties in responding to the scene. They stated that because of the proximity of the rail cars to the bridge superstructure, extricating the injured passengers from the trains took longer than usual. Responders had to use fire department ladders to bridge the distance between the train cars and the adjacent platform and had to delicately maneuver the victims who were on stretchers to avoid injuring them. The last victim was transported from the accident site to the hospital 3 hours and 43 minutes after the collision. A total of 47 ambulances and 1 transit bus were used to transport the injured to hospitals during the response effort.

Williamsburg Bridge was immediately closed to vehicular and pedestrian traffic in both directions. Traffic posts were established to expedite the movement of emergency vehicles. Police assisted in evacuating passengers from the trains, controlling the crowd, controlling traffic, escorting ambulances and emergency equipment, and directing passengers to alternative transportation.

Disaster Preparedness — The FDNY has an ongoing training program with the local railroads to familiarize first-alarm and rescue personnel with the fire safety equipment and facilities at the various rail stations and lines. As part of the program, the FDNY conducts periodic drills after regular duty hours and before the rush hour while the rail system is shut down for repairs and routine maintenance. The drills give fire personnel the opportunity to examine a rail facility, including its fire main system, smoke control system, and handicapped elevators and ramps, and the area around the station. Rescue personnel also receive safety briefings on precautions they should take for themselves and for rail passengers when responding to an emergency in a railroad tunnel or on the right-of-way.

Officials from each of the hospitals that treated patients from this accident stated that they have an emergency disaster plan and routinely participate in disaster drills with local emergency response authorities.

Wreckage — The lead car of the J train, 4461, partially telescoped about 17 feet into car 4664. The rear truck of car 4664 had been knocked off its center casting and had been moved forward about 7 feet, raising the car body about 6 feet into the air. The front end and operating compartment of car 4461 had collapsed inward (see figure 7). A summary of the damage to the individual cars follows.

M train damage — Of the train's eight cars, the first four had no reported damage and the next three suffered cracked bonnets[15] and bent anticlimbers (flanges). The eighth and last car suffered massive carbody intrusion. The anticlimber and front structure was pushed in about 7 feet. The floor was penetrated, and had buckled upward and inward. The vacant operator's cab in the back of the car was totally crushed; no survival space remained.

J train damage — All eight cars suffered some degree of damage. The lead car, which struck the rear car of the M train, experienced massive carbody intrusion on the operator's cab end. The anticlimber and front structure was pushed in about 7 feet. The interior floor was penetrated, and had buckled upward and inward. The entire end of the car was essen tially destroyed up to the horizontal cross member over the center pin. The front seat opposite the operator's cab was totally crushed. The operator's cab was totally crushed with no

[15] A bonnet is the hood that projects over a railroad car.

Figure 7 — Interior damage to the lead car of the J train.

survival space remaining, and the rear wall of the cab was displaced backward. The remaining cars suffered damage to the draft gear (yoke and drawbar) and related parts, cracked bonnets, and bent anticlimbers (flanges).

Emergency Egress Features — According to the NYCT, the preferred emergency exits for the car types that were involved in this accident are the end doors. With the exception of the doors at either end of the train, the end doors are unlocked during passenger operations. The eight side doors normally used for passenger loading are also available for emergency egress. Each of the side doors has two panels that appropriate NYCT personnel or emergency responders can open by unlatching and lifting the bench seat next to the door and pulling a red lever on a door mechanism beneath the seat. The emergency door lever under the seat is not intended for passenger use during an emergency, although it is accessible upon authorization by responders.

Responders can access a car from the outside through the end doors and through four "crew doors" on each side of the car. The crew door is electrically released by key activation. Only appropriate NYCT personnel and emergency responders have keys to the crew doors.

The cars have three glass windows between the doors on each side that are not equipped to operate as emergency egresses. However, in the event of an emergency, responders can break open the windows with firefighting extrication tools.

Crashworthiness — Municipal subway systems are not subject to the FRA oversight. Consequently, the construction of subway cars does not have to be in compliance with the FRA crashworthiness design requirements at 49 Code of Federal Regulations (CFR) 229.141, which address the minimum performance standards of structural components, such as collision posts, anticlimbers, and truck securements. According to NYCT officials, the R-40 and R-42 cars are typical of the lightweight stainless steel vehicles designed and built during the 1960s when economics was the focus of construction and operation. The refurbishment of the cars in the 1980s included installing running gear and air conditioning and

Table 4 —Structural Design Requirements for the Multiple Operated (MU) Electric Locomotive* and the R-68 Subway Car

This chart shows the FRA standards for an MU train having five or more 120,000-pound cars and an empty weight greater than 600,000 pounds and the NYCT contract specifications for an R-68 subway train having eight 90,000-pound cars and an empty weight of 720,000 pounds.

Design Aspect	FRA Standards at CFR 229.141 (criteria in pounds)	NYCT Standards in contract R31468 (criteria in pounds)
Body structure resists a minimal static end load (compression load) of:	greater than 800,000	greater than 500,000
Anticlimbing arrangement resists a vertical load of:	100,000	100,000
Coupler carrier resists a vertical downward thrust of:	100,000	100,000
Main vertical members, that is, the collision posts, must have an ultimate shear value** of:	greater than 300,000	greater than 300,000
Means of locking the truck to the body must have an ultimate shear value of:	greater than 250,000	greater than 150,000

* defined in 49 CFR 229.5 (k)(2) or (3)

** at a point even with the top of the underframe. If reinforcements are used, it shall have full value 18 inches above the top of the underframe, then taper to a point approximately 30 inches above the top of the underframe.

cosmetically changing the carbody, but it did not include retrofitting the structural features.

The NYCT's current procurement specifications for carbody construction include improved primary and secondary collision posts, progressive crush resistance, carbody stress analysis, and truck securing devices. Table 4 compares the current NYCT specifications with the FRA crashworthiness design requirements at CFR 229.141.

Tests and Research

Signal Tests — NYCT inspectors arriving shortly after the accident determined that all relays, aspects, and trip arm positions were correct, given the locations of the trains. They performed several tests, including shunt tests, grounds tests, and a megger[16] test, on the track circuitry and signals, and found no anomalies or unsafe conditions. When Safety Board investigators arrived on scene, they conducted their own tests of the signal system and determined that all track relays activated within prescribed limits and that all signals cycled through in proper sequence.

On June 10, 1995, NTSB investigators along with parties to the investigation[17] conducted several tests designed to replicate the circumstances of the Williamsburg Bridge accident. Using the same type and number of subway cars as were involved in the accident, investigators performed visibility, sight-distance, stop arm, and train stopping tests. Mechanical and track personnel were positioned on the bridge to mark stopping points, measure distances, and ensure car wheels rotated during braking. Safety Board investigators and party representatives in the lead car

[16] A test of signal circuitry conductors and cables to ensure that the insulation of wires and connected apparatus have an allowable resistance of 500,000 ohms or more.

[17] Representatives of the New York Public Transportation Safety Board, the Metropolitan Transportation Authority Office of the Inspector General, the NYCT, and the State of New York Department of Labor.

of the J test train observed and recorded events as they occurred.

Sight Distance Tests — Investigators conducted a three-part visibility test about the same time of day that the accident occurred. An eight-car train of R-42 cars, simulating the M train, was positioned so that its end was at the point of collision. As the test J train with eight R-40 cars departed Marcy station and slowly ascended the Williamsburg Bridge approach, the operator stopped whenever he could identify given features of the stationary M train. Investigators recorded the following stopping points and their relation to signals: At 1,632 feet, about 100 feet before signal J2-141, the operator could discern the back of a train; at 1,382 feet, about 200 feet before signal J2-138, he could identify the train's rear marker lights; at 1,141 feet, about 400 feet before signal J2-136, he could see the train's entire end. Investigators identified no problems with the illumination of the signal bulbs or with the angle of the morning sun on the signal.

Braking Tests

Emergency Braking — Safety Board investigators conducted all braking tests using the Kustom Signals Falcon radar unit, which has a +/- 1-2 mph tolerance. Investigators had the test M train removed from the bridge and placed markers at the point of impact to represent the end of the M train. Testers went by signal J2-128 twice at maximum speed to test the operation of the trip arm and the train's trip cock and the effectiveness of the train's braking system in emergency.

During the first run, the test train had attained a speed of 34 mph by the time it passed signal J2-128 and activated the trip arm, which struck the trip cock causing the train's brakes to go into emergency. The test train passed the markers representing the rear of the M train at 18 mph; it came to a stop 76.5 feet beyond the collision point and 364.5 feet from the in-track trip arm.

Investigators repeated the conditions of the first run during a second braking test to ensure the accuracy of equipment performance. During the second test, the J train had attained a speed of 34 mph when the trip arm activated at signal J2-128 and the train went into emergency braking. Again the train passed the point of collision at 18 mph. In this test, it came to a stop about 70.5 feet beyond the collision point and 358.5 feet from the in-track trip arm.

Full-service Braking — This braking test duplicated the conditions of the previous tests, except that the operator manually put the train in a full-service brake application as the train passed signal J2-128. The train had attained a speed of 33 mph when it reached signal J2-128 and the operator made a full service brake application. The train stopped 125 feet 10 inches short of the collision point and 162 feet 2 inches from the trip arm near signal J2-128.

Maximum Safe Speed — Based on the findings of the previous tests, investigators calculated that the maximum possible speed a train could travel so that it would stop short of the collision point after triggering the trip arm and activating the emergency braking was 30 mph. In the fourth braking test, the train had attained a speed of 29 mph when the trip arm initiated an emergency brake application. The train came to a stop 12 feet 8 inches short of the collision point. Investigators then had the operator make another pass at a target speed of 25 mph. The train's speed was 22 mph when the trip arm activated and triggered an emergency brake application. The train came to a stop 109 feet 8 inches short of the collision point.

Investigators conducted another test run to aid in determining a safe interim operating practice for movement over the Williamsburg Bridge. The train operator was instructed to start from a stop at Marcy station and to place and leave the power control handle in second power. The train was traveling 15 mph when it passed the trip arm, which triggered an emergency brake application. The train stopped 196 feet 8 inches before the point of impact.

Trip Arm Setting Tests — At the time of the accident, the trip arm was 2 3/8 inches above the top of the rail. During the postaccident testing, investigators conducted two tests to determine the efficacy of the trip arm, first at a height of 2 inches above the rail and then at a height of 1.75 inches above the rail. The test train started from a stop at Marcy station and proceeded at maximum attainable speed by the trip arm. In each test, the trip arm was triggered and made contact with the car trip cock, initiating an emergency brake application. In the first run, the train was traveling 34 mph when the trip cock was actuated, which resulted in the train stopping 52 feet 8 inches past the point of impact. In the second run, the train speed was 33 mph when the trip cock was actuated, which resulted in the train stopping 57 feet past the point of impact.

Subsequent Braking Tests — During the braking tests on June 10, the train stopped during the full-service braking test in a significantly shorter distance, 162 feet, than it did during the emergency braking tests (364 and 358 feet, respectively). The NYCT officials contended that the June 10 braking test results were an anomaly and not representative of true braking performance. The Board therefore conducted additional braking tests on March 5-6, 1996, on an area of the NYCT F line between 18th Avenue and 22nd Avenue where the track is tangent with minimal grade.

Investigators had three R-40 married pairs[18] with the minimal required operating equipment taken out of revenue service for the March tests. The operating cabs were equipped with instruments to record the following eight functions: speed, time, and distance; deceleration/ acceleration rate; motor current; brake pipe, EMV activation; and wheel temperature one wheel/car set.

[18] Investigators elected to test two-car sets because individual cars brake independently from one another. That is, a train of two cars should brake in the same distance as a train of four, six, or eight cars.

Investigators planned to run the test trains one at a time at 20 mph, 30 mph, and 40 mph, first in one direction and then back in the other direction, applying the brakes in one mode when the target speed was reached and then noting the recorded stopping distance. However, on March 5, 1996, the Safety Board was able to test only the first car set because of problems with weak and dead batteries in the cars. On the following day, it rained, resulting in rail conditions that were not comparable to the conditions during the earlier tests. Because rain was forecast for the rest of the week and because much of the NYCT rail system is exposed to the weather, the parties agreed to conduct the tests to determine what kind of braking performance was possible under such conditions. The parties also agreed to couple the second and third train sets together because most NYCT train consists have eight cars. As a result, the test train could be operated only in the south direction because only the second car set was equipped with recording instruments. Table 5 shows the results of these tests.

The Safety Board examined the maintenance records for both trains. Records show that the NYCT had removed and renewed the air brake valves every 6 years and had tested, inspected, and serviced the cars on both trains every 66 days or 10,000 miles in accordance with the manufacturer's specifications. Car 4461 had last received air brake maintenance service in 1994.

Oversight of Rail Rapid Transit Safety

The Board's concern about the oversight of rail rapid transit safety dates back more than 20 years. In 1971, as a result of the Safety Board's special study (NTSB/RSS-71/1) exploring the role of the Urban Mass Transportation Administration (UMTA) (now the Federal Transit Administration) in developing safe transit systems, the Board urged the UMTA to require that all rail rapid transit applications for capital improvement, demonstration, and research and

Table 5 — Results of the March Braking Tests

		Targeted Speed/Braking Modes (Full Service = Full Svc; Emergency = Emer)					
Test*	**Measurements Recorded**	**20 mph**		**30 mph**		**40 mph**	
		Full Svc	**Emer**	**Full Svc**	**Emer**	**Full Svc**	**Emer**
No. 1							
2 cars	Actual Speed (mph)	19.1	19.5	29.9	29.0	38.3	37.5
North	Wheel Temperature	90^0 F	97^0 F	87^0 F	94^0 F	90^0 F	95^0 F
Dry Rail	Stopping Distance (ft)	120.5	104.0	238.6	225.5	347.3	358.1
No. 2							
2 cars	Actual Speed (mph)	21.0	19.3	30.7	30.1	40.3	39.5
South	Wheel Temperature	67^0 F	74^0 F	67^0 F	68^0 F	76^0 F	83^0 F
Dry Rail	Stopping Distance (ft)	143.6	110.6	262.5	246.1	399.6	402.0
No. 3							
8 cars	Actual Speed (mph)	20.8	20.0	31.3	29.7	39.6	39.2
South	Wheel Temperature	57^0 F	48^0 F	48^0 F	59^0 F	48^0 F	61^0 F
Wet Rail	Stopping Distance (ft)	135.6	170.1	283.4	318.1	398.4	490.4

*Test Conditions: Column one shows the number of cars, direction of travel, and condition of the rail for each test.

development grants include a system safety plan for the proposed project.[19]

Because of several accidents in the mid and late 1970s involving the Chicago Transit Authority and the Greater Cleveland Regional Transit Authority, in March 1978, the Safety Board made the following recommendation to the Secretary of the U.S. Department of Transportation (DOT):

<u>R-71-15</u>

> Develop oversight capability to insure that the safety of rail rapid transit systems will be regulated and enforced by a responsible State or Federal agency. Within the Department of Transportation, accountability for the oversight should be assigned to the Administration that controls Federal grants to aid rail rapid transit.

Within a month of the Board issuing the recommendation, the Secretary of Transportation approved the delegation of complete responsibility for rail rapid transit safety within the Department to the UMTA and advised the Safety Board that a new rail rapid transit safety program was being developed.

In 1980, the Safety Board convened a 2-day public hearing on rail rapid transit safety. The hearing was prompted in part by an increasing concern about the adequacy of the safety oversight of rail rapid transit systems, particularly the oversight of fire safety and emergency evacuation of passengers from underground or underwater tunnel locations. In conjunction with that study, the Board issued the following two recommendations to the Secretary of the Department of Transportation:

<u>R-81-01</u>

> Propose legislation to explicitly authorize the Secretary of Transportation to regulate the safety of rail rapid transit systems which receive Federal financial assistance. Such legislation should

[19] Safety Recommendation R-71-15 was eventually classified "Closed—Acceptable Action" in 1976 when UMTA awarded a contract to the Transit Development Corporation to provide technical support to UMTA in its research and development programs.

include the authority to establish Federal minimum safety standards, to enforce compliance, to conduct inspections, to conduct investigations of accidents and incidents, and such other general powers and duties as are necessary to provide for effective safety oversight.

R-81-02

Pending the enactment of legislation conferring direct regulatory authority, require the Urban Mass Transportation Administration to establish Federal guidelines for equipment and operations, to aggressively utilize existing grant programs and investigative authority to promote conformance with Federal guidelines, and to conduct a program of substantially increased safety oversight of Federal assisted rail rapid transit systems.

In response to these safety recommendations, the Secretary stated in April 1981 that Federal regulatory authority was not needed and that "rail transit safety is a local responsibility that is best handled by the State and local decisionmakers who are accountable for the safe, effective, and efficient operation of the rail transit systems." At the time, the UMTA considered itself to be a financial assistance agency rather than a regulatory agency, as are the other modal administrations within the DOT, and steadfastly maintained that regulation of the rail rapid transit industry was not warranted.

In its 1981 report of eight NYCT subway train fires that occurred during a 13-month period beginning in June 1980, the Safety Board concluded that "if the need for safety oversight of the NYCTA is to be met, it must be met at the State or local level." Consequently, the Board issued the following Safety Recommendation to the Governor of the State of New York:

R-81-116

Initiate legislative and/or executive action to authorize a new or existing independent agency to oversee and regulate the safety of the New York City Transit Authority.[20]

On July 12, 1982, the Governor of New York responded that legislation had been proposed to create a new independent agency to oversee and regulate the safety of the NYCT. The Governor also stated that New York was fully committed to public transportation safety, however; New York had opposed this legislation in the past because it would do no more than add yet another agency to an already crowded field. The Governor stated that the State DOT was developing a proposal to accomplish the objective of the legislation within the department, which he considered to be a more logical course of action. On January 27, 1983, the Safety Board responded that independent safety oversight from the State DOT would meet the intent of the recommendation and classified Safety Recommendation R-81-116 "Open—Acceptable Alternate Action" pending further action.

Less than 1 ½ years after issuing Safety Recommendations R-81-01 and -02, the Safety Board concluded that detailed regulation of rail rapid transit safety should not lie with the Federal government and closed these recommendations as reconsidered. The Safety Board had concluded in the early 1980s that regulation and enforcement of transit system safety could be handled by the States. However, the lack of action by some States in response to Board recommendations and the occurrence of additional accidents in the mid and late 1980s prompted the Board in 1991 to conduct a study

[20] The Safety Board classified Safety Recommendation R-81-116 "Closed—Acceptable Alternate Action" on July 25, 1986. The Board issued similar recommendations to the Governors of Ohio and Pennsylvania in 1987 following the Board's investigations of accidents involving the transit properties in those States–the Greater Cleveland Regional Transit Authority and the Southeastern Pennsylvania Transportation Authority, respectively.

to examine the current oversight of rail rapid transit systems and to determine whether oversight responsibility was being met at the State or Federal level. The Board expressed concern in that study that oversight responsibility was not being met by all the States and that the FTA lacked a methodology to ensure independent oversight for FTA-funded and FTA-assisted systems. As a result of that study, the Safety Board issued the following Safety Recommendation to the Governors of States in which a rail rapid transit system operated:

> R-91-37
>
> Develop or revise, as needed, existing programs to provide for continual and effective oversight of rail transit safety.

The Board concurrently issued the following Safety Recommendation to the FTA:

> R-91-33
>
> Document and evaluate the effectiveness of existing State oversight activities and to develop guidelines for use by State and local governments that address the critical elements of an effective oversight program.

Subsequent to the Safety Board issuing these recommendations in 1991, the Intermodal Surface Transportation Efficiency Act of 1991 (P. L.-240), enacted into law on December 18, 1991, added Section 289 to the Federal Transit Act. This section directed the FTA to issue a rule requiring those States in which a rail fixed guideway system operates that is not regulated by the FRA to designate a State oversight agency to be responsible for overseeing the safety of the guideway system.[21]

[21] Once this rulemaking was underway, the Safety Board determined through initial correspondence with the States that any effort by the States to address the full intent of the Board’s recommendation would await the publication of a final rule by the FTA.

On December 27, 1995, the FTA published its final rule, "Rail Fixed Guideway Systems; State Safety Oversight," in the *Federal Register* (Vol. 60, No. 248). The rule covers not only such systems as WMATA and BART, but also monorails, trolleys, light rail systems, and automated guideways. In short, the rule covers any system that receives funding under FTA's formula grant program or is used in the calculation of “fixed guideway route miles.”

Given that the FTA has now published a final rule, the Safety Board is following up with the 10 States and the District of Columbia that have rail rapid transit systems to determine what efforts are underway to address the FTA regulatory action in a way that will meet the intent of the Board's recommendation.

New York State Safety Board

History — The New York State Public Transportation Safety Board (PTSB) came into existence in 1984 and was placed under the jurisdiction of the New York State DOT. The PTSB has responsibility for overseeing the safe transportation of passengers who use State-assisted public transportation in the State of New York. More than 120 different public transportation systems, which include more than 16,000 buses, 6,000 subway cars, and 2,000 commuter rail cars, operate in the State of New York. The transit agencies of the Metropolitan Transportation Authority, which includes the New York City Transit (rail and bus), the Staten Island Rapid Transit Operating Authority, the Metropolitan Suburban Bus Authority, the Long Island Rail Road, and the Metro North Commuter Railroad, account for more than 90 percent of the transit riders in the State of New York. The PTSB also oversees the Niagara Frontier Transportation Authority light rail system in Buffalo, New York, and the New Jersey Transit.[22]

[22] About 125 bus systems are under the jurisdiction of the NYSPTSB.

The PTSB is empowered by legislative authority to:

> investigate accidents occurring on or involving public transportation systems, whether publicly or privately owned;
>
> establish an accident investigation reporting and analysis procedure to improve public transportation safety;
>
> review, approve and monitor a system safety plan to be submitted by each transportation system that is eligible for Statewide Transportation Operating Assistance;
>
> conduct systematic audits of system safety programs; and
>
> recommend the establishment of rules, regulations, or equipment and safety standards.

The PTSB has 15 personnel positions, of which 4 positions are devoted to rail safety. The chief of rail safety is in Albany, New York, and a supervisory investigator and two investigators are assigned to the Brooklyn office. At the time of the Williamsburg Bridge accident, both rail investigator positions were staffed. In July 1995, one investigator position became vacant.

PTSB Recommendations to NYCT — As a result of its investigations in recent years, the PTSB has made a number of recommendations to the NYCT in the areas of signal design and braking. Following an August 28, 1991, train derailment at the Union Square station in which 5 passengers died and 129 passengers were injured, the PTSB found that the NYCT "signal system is not designed to be an absolute train control system and is limited with respect to train speed control." The PTSB report noted that the home signal was grade timed and equipped with a tripping device but was unable to successfully reduce the train's speed and prevent the train from derailing. As a result of its investigation, the PTSB recommended that the NYCT "install at least two blocks of 'single shot' time controls signals approaching all interlockings." The PTSB said that such an installation would "successfully reduce excessive train speed approaching interlockings until such time that a state of the art train control system can be installed."

The NYCT enacted a number of alternatives to provide overspeed protection during diverging moves, include enforcing a "call-on" aspect at the approach home signal, which was a more restrictive measure than requested by the PTSB.

After receiving a report of the NYCT's interim changes, the PTSB made the following recommendations to the NYCT:

- Explore the feasibility of enhancing braking capability by combining dynamic and pneumatic braking in the emergency braking mode.
- Adjust all car equipment braking ratios to conform with the subway car brake test curves and signal system design standards.
- Install speedometers on all cars.

According to PTSB officials, in a follow-up meeting with NYCT officials, "the PTSB staff has remained firm with its expressed position that to ensure a systematic approach to rail passenger safety, the signal system must be designed to remove human error to the greatest extent possible."

On September 24, 1992, the NYCT responded to the PTSB regarding its recommended modifications to the car brakes:

> Car equipment engineering has explored the feasibility of combining dynamic and pneumatic brake during emergency brake applications. New York Air Brake and WABCO have submitted their comments and sug-

> gestions (attachments). We advise against this recommendation because it would compromise the "fail safe" aspect of the emergency brake system and would be very expensive to implement. Major modification of the existing brake and propulsion systems would be required, including a microprocessor controlled slip/slide system. The NYCT friction brake system is capable of providing the maximum retardation rate for the existing wheel to rail adhesion levels.

The PTSB wrote the NYCT on November 30, 1992, regarding incorporating a combined dynamic and pneumatic braking system into new design and procurement. On January 27, 1993, the NYCT said that it had "no plans to pursue this recommendation..." and provided the PTSB with an update of modifications that the transit company was making to the braking components of various car types.

Following its investigation of the Franklin Avenue accident on January 5, 1993, the PTSB found that the probable cause of the accident was the improper operation of the train by the train operator. The PTSB acknowledged the NYCT's efforts over the previous 2 years to modify the braking systems of its cars but asked, among other recommendations, that the transit company "Identify the minimum braking distance that the signal system provides system-wide and take corrective action to ensure that 100 percent of the braking distance requirements listed in the braking distance standards is available."

On March 30, 1993, the PTSB advised the NYCT that its recommendation about adjusting car equipment to conform with the signal design standards remained open because of the recent braking problems identified in the collision at Franklin Avenue on January 5, 1993. In a later letter, the PTSB set a 2-year deadline for the NYCT to comply with the recommendation. The NYCT responded:

> Due to the extensive nature of the work involved, shortage of personnel available to conduct these tests, limited track test area and test equipment utilized, the schedule cannot be met. Nevertheless, in view of the urgency expressed by the PTSB and the Office of System Safety to expedite this schedule, we have revised it to reflect that all car classes will be completed by 1996 instead of 1998. Attached is a copy of Car Equipment's initial look into the fleet's braking characteristics that we mentioned in our May 14, 1993, letter.

The PTSB next wrote the NYCT requesting that the transit company provide it "with copies of the final brake testing reports for each car class as they are completed" and stating that the PTSB staff would "continue to monitor this program until its completion in 1996."

American Public Transit Association — The American Public Transit Association (APTA) is a private, non-profit trade association that represents the American public transit industry in the United States and Canada. The APTA's members include motor bus and rapid transit systems; organizations responsible for planning, designing, constructing, financing, and operating transit systems; businesses that supply products and services to the urban transit industry; academic institutions; and public interest groups.

In 1982, the APTA board of directors created the Rail Safety Review Board (RSRB) to "provide the rail transit industry with the support necessary to maintain adequate self-regulation programs and a high level policy development forum for all matters concerning system safety." To achieve this purpose, the RSRB directs, among other activities, (1) a rail safety audit program, (2) a rail accident investigation service, and (3) a rail safety review service.

Although any transit system that is currently operating, building, planning or contemplating a rail transit system is eligible for membership in the RSRB, only those transit systems that are currently operating a rail transit system may ask to participate in the rail safety audit program. To participate in the rail safety audit program, the transit agency must develop and implement a system safety program plan according to APTA's provisions, adopt the principle of system safety, agree to be audited for conformance with the system safety program plan, and pay the required participation fee. Following submission and approval of its system safety program plan, a transit agency is scheduled for audit once every 3 years. APTA completed an audit of the NYCT in 1990 and had scheduled another audit for December 1994. According to an APTA representative, the NYCT audit had to be rescheduled until 1996 because of various conflicts. The audit was scheduled to be completed on August 28, 1996, and the resulting report was to be published sometime thereafter.

The APTA's Rail Safety Review Board also provides a rail safety review service and an accident investigation service. A participating transit system may request a review of its safety program or any specific element of its safety program. Likewise, any participating transit system that experiences an accident may request that the accident be investigated. In both instances, APTA convenes a panel of rail transit experts from the transit community. Following the review or investigation, the panel will issue findings or recommendations to the transit authority, outlining safety improvements that can be made to prevent future occurrences.

ANALYSIS

General

This analysis is divided into three main sections. In the first part, the Safety Board identifies factors that can be readily eliminated as causal or contributory to the accident as a result of its investigation. The second section recounts the accident sequence, citing actions and events resulting in problem conditions. In the final section, the Board discusses the findings that support each safety issue identified in this investigation.

From personnel statements, inspection reports, and postaccident examinations, the Board concludes that the track, the train equipment, and the signal system functioned as designed.

Weather and visibility were not factors. Witnesses stated that it was clear and sunny. The M train operator testified that he could clearly see the signals and the train ahead of him from a distance of 30 car lengths. During sight distance tests conducted at the same time of day and in similar weather conditions, Safety Board investigators determined that the illumination of the signal bulbs was adequate and that the morning sun did not reflect on the signal glass. Moreover, no signage or material used in the bridge construction project was near or blocked any of the signals. Therefore, visibility at the time of the accident was adequate for the J train operator to have observed the train ahead of him and to have seen and responded to the signal indications.

Results of postaccident toxicological tests indicate that the J train operator was not impaired by alcohol or drugs. He reportedly was in good health and was an experienced and qualified NYCT train operator.

The Accident

On June 4, 1995, the J train crew went on duty at 2338 following their usual 64-hour RDO period. During his time off, the J train operator had slept during the time period that he normally worked. The J train crew completed the first two of their regular round-trip runs between Jamaica Center and Chambers Street station without incident. The conductor stated that the train departed on time from Jamaica Center on their third and final round trip at 0531. He stated that the train operator seemed to be operating the train in the usual manner, at the proper speeds, and that all the station stops were routine.

The M train departed on time at 0548 from Metropolitan station. As it approached the Williamsburg Bridge, the M train was following a work train, which it usually did not do on its morning runs. The M train operator had to stop repeatedly to wait for the work train; however, he failed to radio and inform the command center dispatcher of his stops as required by the NYCT's operating rule book.

According to an off-duty NYCT employee who happened to be on board when the J train departed Marcy station, its operator accelerated as train operators typically do on a incline. Before this accident, the approach to the bridge had no speed restriction, and NYCT operating procedures allowed train operators to attain whatever speed the train was capable of achieving. However, the signal at J2-130 would have been displaying a yellow aspect, meaning "proceed with caution, be prepared to stop." The J train operator did not take any precautionary measures, such as slowing the train, at signal J2-130, and failed to comply with the indication at signal J2-128, which would have been displaying a red aspect. Postaccident findings[23] and speed and braking tests indicate that the J train was traveling about 34 to 36

[23] During examination of the wreckage, investigators found the power cam shaft in the full power position.

mph when it passed the J2-128 signal. The train passing the stop signal triggered the automatic trip arm, which struck the train trip cock, activating the emergency braking. Despite the proper activation of the trip arm and the train's emergency braking, the distance between signals J2-128 and J2-125 was not sufficient for the J train to stop safely and it struck and penetrated the rear of the M train. The J train operator was killed in the accident.

From its investigation, the Safety Board identified the following safety issues in this accident: the fatigue of the J train operator; the adequacy of NYCT oversight of communications rules compliance; and the adequacy of spacing between signals for braking. In addition, the Safety Board looked at positive train separation, crashworthiness, and the oversight of the New York State Public Transportation Safety Board (PTSB).

Fatigue of the J Train Operator

The J train operator had served as a motorman in the New York subway system since 1981 (14 years) and had operating experience on the J line for several years. His most recent performance evaluation described his overall operation as "good." The Safety Board attempted to determine why a capable train operator proceeded past restrictive signal indications at high speed without slowing and how the accident could have been prevented. From witnesses' statements, the Board determined that no loud noises or passenger activity occurred on board the J train that may have distracted him. The pedestrian sidewalk next to the bridge was being replaced; however, no construction signs or material hindered the operation of the subway trains or affected operators' lines of sight. Moreover, the construction work, which might have been a source of distraction, had not yet begun at the time of the accident. The Safety Board considered whether the sun might have been a factor. The M train operator indicated that he had no problems seeing the signals or the trains ahead. He stated that he could see the train ahead of him from a distance of "about three or four (8-car) train lengths." Sight distance tests conducted after the accident confirm that a train stopped at signal J2-120 was visible from about 1,632 feet. The most plausible explanation for the behavior of the J train operator is that he was falling or had fallen asleep.

The train operator's overt behavior and performance before his last approach to the Williamsburg Bridge showed no indication of impairment. Station dispatchers who had observed him before the accident trip concluded that he was fit for duty; the J train conductor observed no instance of improper train handling during the trip; and the off-duty train operator who had observed the J train operator about 12 minutes before the accident thought that he appeared alert and attentive. After departing Marcy station, he successfully negotiated the curve before the Williamsburg Bridge approach before applying full throttle to the train.

Despite observations that the J train operator was alert and fit for service, anecdotal evidence exists that he fell asleep while proceeding up the bridge approach. After applying full throttle, he made no other responses during the next minute to signal aspects requiring first that he prepare to stop (yellow) and then that he stop (red). After he passed the J2-133 signal, he had about 5 seconds to comply with the yellow aspect at J2-130, but failed to slow his train. Being an experienced train operator and being familiar with the J line, he would have known that as a precautionary measure he had to slow his train in order to stop at the red signal in the block ahead. After he passed the J2-130 signal, he had about 6 seconds to stop in response to the red J2-128 signal, but did not attempt to do so.[24]

The position of the J train operator's body after the accident supports the finding that he probably fell asleep. About 7 seconds elapsed between the time that the J train went into

[24] Postaccident examination indicated that the emergency braking was activated by the trip cock and not by the operator applying the brakes.

emergency braking and the time of impact. When a train goes into emergency braking, the brake system emits a distinctive noise, recognizable by any crewmember. Both the conductor and the off-duty operator on the J train reported hearing the chow sound of the emergency brake. Had the J train operator been alert, he would have been able to detect that a collision was imminent and probably would have tried to vacate the compartment to avoid injury. However, investigators found his body in his seat and no indication that he had turned or moved to leave the compartment. His failure to take action in a life-threatening situation strongly suggests that he was either asleep or had just woken up and was too disoriented or sluggish upon waking to respond.

The Safety Board attempted to determine why the train operator might have been fatigued. One factor to examine when investigating the role of fatigue is the time of day when the work is done. The accident happened at 6:12 a.m., a time that coincides with a person's primary period of sleepiness. For many people, including shift workers who work between midnight and 6 a.m., the best condition is lowered alertness, and the worst case is falling asleep.[25] After the train operator applied full throttle, the train's 1-minute climb up the bridge would have been ample time for him to have fallen asleep.

The accident occurred on Monday, the first day when the train operator changed from his weekend schedule of sleeping at night to his weekday schedule of working at night. A significant problem in rotating work shifts is the time it takes for the person's internal biological, or circadian, clock to change. When a person changes his work/rest schedule, his body does not adjust immediately. Adapting to the new sleep/wake schedule may take several days to several weeks. A failure to adjust to schedule changes impairs performance, diminishes alertness, and increases reaction time. Studies have shown that shift workers who rotate schedules are especially prone to fatigue on both the first and second nights of the work week. In this case, the J train operator, who was working at the time when he was asleep on the previous day, did not have the necessary time for his circadian rhythm to match his new sleep-wake cycle. As a result, he probably was not prepared to stay awake all night.

The NTSB study, *Factors That Affect Fatigue in Heavy Truck Accidents*,[26] concludes that the most critical factors in predicting fatigue-related accidents are the duration of the most recent sleep periods, the amount of sleep in the past 24 hours, and split sleep patterns. The J train operator's last sleep period (a Sunday evening nap) was probably less than 3 hours. He probably had received only about 6 hours of sleep or less in the 24 hours before the accident and was not sufficiently rested. The Safety Board concludes that the J train operator failed to take action to stop his train on Williamsburg Bridge because he was asleep.

The Safety Board has been concerned about the factor of fatigue in transportation for many years. In 1990, the Board completed a study of 182 heavy truck accidents that resulted in driver fatalities. The primary purpose of this study was to assess the role of alcohol and other drugs; however, the study found that fatigue was the probable cause or a factor in 31 percent of the accidents.[27]

The Safety Board has also found fatigue to be prevalent in railroad accidents. The Board determined that the probable cause of a January 1988 head-on collision of two freight trains in which the engineers and brakemen died was the "sleep-deprived condition of the engineer and

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[25] Dinges, D. F. , 1989. The nature of sleepiness: causes, context, and consequences. In: Strunkard, A., eds. Perspectives in behavioral medicines: eating, sleeping, and sex. Hillsdale, N. J.: Lawrence Erlbaum: 147-179.

[26] Safety Study (NTSB/SS-95/01).

[27] Safety Study *Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-To-The-Driver Heavy Truck Crashes,* (NTSB/SS-90/01).

other crewmembers of [the westbound train], which resulted in their inability to stay awake and alert, and their consequent failure to comply with restrictive signal aspects."[28] Investigators found that none of the crewmembers on the westbound train had had more than 2 hours of sleep during the 22 to 24 hours preceding the accident.

Following its investigation of a November 1990 head-on collision of two freight trains near Corona, California, in which the entire 3-man crew of one train and a brakeman on the other train were killed, the Safety Board found that the errant crewmembers were either asleep or too sleepy to respond.[29]

Over the last several years, the NYCT J train operator had periodically been observed at work in a fatigued condition. His personnel file contained a disciplinary action (reprimand) for sleeping in a darkened crew room while on duty on January 18, 1989, at 2:01 a.m. In addition, an NYCT train operator who had worked with the J train operator on and off for about 2 years recalled him saying that he had "barely made it this trip" because he had trouble staying awake. She stated that he would get tired during an 8-hour midnight tour and that "he and other motormen" had problems trying to stay awake between 3 a.m. and 6 a.m. She stated that, contrary to company policy, crewmembers "all took naps at work during the midnight tour." The J train conductor echoed her observations. He testified that his RDO before reporting to his first night of work had been hectic and that he was feeling the effects of fatigue at the time of the accident. He added that anyone who had worked the midnight shift knows that "there's certain times of the night you feel a little fatigue."

Recent studies, including research performed at the NASA Ames Fatigue Countermeasure Program, have identified effective countermeasures to combat fatigue. One acute, short-acting operational countermeasure to minimize or mitigate the effects of sleep loss, circadian disruption, and fatigue in flight operations is the use of strategic napping. A study examining the effects of planned cockpit rests during long-haul operations found that pilots who slept in the cockpit for an average of 26 minutes during low workload periods maintained higher levels of vigilance and alertness compared to pilots who did not nap.[30] Additional research has shown that a single 45-minute nap before a night without sleep can prevent significant loss of performance capability and fatigue throughout the night.[31] The Safety Board agrees that the use of naps as a means of preventing fatigue before its onset is a worthwhile countermeasure and a strategy that the NYCT should consider acceptable and advantageous. The use of punitive or disciplinary measures, such as employee reprimands or suspensions, simply is not effective in combating a physiological condition. Strategic napping by train operators and conductors could occur during extended non-operational periods on their shifts. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Federal regulations do not require that fatigue educational programs be developed or

[28] Railroad Accident Report--*Head-End Collision of Consolidated Rail Corporation Freight Trains UBT-506 and TV-61 Near Thompsontown, Pennsylvania, January 14, 1988*. (NTSB/RAR-89/02).

[29] Railroad Accident Report--*Atchison, Topeka, and Santa Fe Railway Company (ATSF) Freight Trains ATSF 818 and ATSF 891 on the ATSF Railway, Corona, California, November 7, 1990* (NTSB/RAR-91/03).

[30] Rosekind, M.R., Graeber, R.C., Dinges, D.F., Connell, L.J., Rountree, M.S., Spinweber, C.L., and Gillen, K.A. (1994). *Crew Factors in Flight Operations IX: Effects of Planned Cockpit Rest on Crew Performance and Alertness in Long-Haul Operations*. (National Aeronautics and Space Administration Technical Memorandum 108839).

[31] Rosekind, M.R., Gander, P.H., Miller, D.L., Gregory, K.B., McNally, K.L., Smith, R.M., & Lebacqz, J.V. (1993). "NASA Ames Fatigue Countermeasures Program." *FAA Aviation Safety Journal*, 3(1), 20-25.

incorporated in training for covered employees or supervisors in transit operations. Therefore, the Safety Board is pleased that the NYCT took the initiative of contracting for a fatigue study and is incorporating a fatigue educational awareness program into its fitness-for-duty evaluations. The Board notes, however, that the videotape developed on safe operating procedures for train operators only briefly addresses the need for employees to be rested and alert and the need for employees to get between 6-8 hours of sleep before reporting to work. The video does not discuss other relevant issues regarding fatigue, particularly sleep-related issues relevant to night-shift workers. Although the Safety Board commends the NYCT's initiative in providing this training, the Board believes that the transit company's fatigue educational program should be expanded. The Safety Board believes that the NYCT should develop and disseminate a training module that tells train operators about the hazards of operating trains while fatigued. The module should include information about the need for an adequate amount of quality sleep, about the fact that a train operator can fall asleep suddenly and without warning regardless of his age or experience, about the behavioral and physiological consequences of sleepiness, and about strategies for avoiding sleep loss, such as strategic napping.

During its investigation of this accident, the Safety Board contacted six major transit agencies and found that none of them provides fatigue-related training in its employee training program. In a transit system that is not fail safe and is vulnerable to human error, the issue of fatigue is of great concern. To help reduce the number of fatigue-related accidents, fatigue training and education is critical for employees in safety-sensitive positions. The Board, therefore, believes that the DOT's FTA, in cooperation with APTA, should develop and distribute a model fatigue awareness program for transit agencies to use in their fitness-for-duty training for supervisors and employees in safety-sensitive positions.

NYCT Oversight of Communications

Had the J train operator been alerted by the command center that a vehicle was stopped on Williamsburg Bridge, this accident might have been avoided. Under normal traffic conditions, the M train typically would have been leaving the bridge in Manhattan as the J train entered the bridge from Brooklyn. The J train operator, who was experienced on this line, probably was accustomed to traveling across the bridge on green signals and not experiencing delays or stopping for trains ahead.

Stops between stations generally are not planned, and collision-avoidance depends largely on the appropriate and timely response by the train operators approaching a stopped vehicle. One way to help prevent rear-end collisions is to alert operators of trailing trains that they may need to make an unexpected stop for a train ahead. The NYCT employee operating procedures at Rule 40, "Signals," specifically state that train operators encountering a red automatic signal must immediately radio the dispatch command center that they have stopped. Upon receiving such notification from an operator, command center personnel are to inform stopped trains and any following trains of the reason for the red signal. The Safety Board is concerned that the rule requiring train operators to immediately call the command center at a red signal as written and as placed in the employee operating manual and revision bulletin is ambiguous and confusing to train operators. The paragraph about the need to immediately call the command center at a red signal immediately follows procedures for keying by a red signal. Although these two procedures are independent of each other, their juxtaposition in the rule book suggests that they are linked and that operators are to call the command center only when they are seeking permission to key by a red signal. Consequently, train operators who have to stop and who do not intend to key by a signal may believe that they do not have to call the command center immediately. This problem was identified during interviews conducted separately by the Safety Board and by the New York City Council's Committee on Transportation with NYCT train operators and dispatchers. Few of those interviewed could correctly list the communications procedures they had taken or were supposed to take when they had to stop at a red signal. The Safety Board concludes that the NYCT operating manual at Rule 40 (m), which stipulates that train operators must immediately notify the command center when they are stopped at red signals, can easily be misinterpreted and is inconsistent with the NYCT's actual mode of operation.

The Board is aware that the NYCT tried to address the problem of employees misinterpreting Rule 40 (m) by issuing a special bulletin revising the required procedures. However, as evidenced by the responses from the employees interviewed after the accident, this method of advising employees of a procedural change is not totally effective and results in hit-and-miss compliance, at best. The Safety Board believes that operators would better understand that they are to immediately contact the command center under all circumstances upon stopping at a red signal if this procedure were presented at the beginning of Rule 40 (m). Further, the NYCT needs to enact measures to ensure that employees read, understand, and adhere to the rules.

The Safety Board examined several NYCT accidents (see table 7) in which the operators of the striking trains simply did not know that another train was stopped ahead of them and consequently did not take any precautionary measures. In all cases, the operators of the struck trains failed to call the command center to report that they were stopped at a red signal. Had they reported the delays, the command center dispatchers could have assessed the circumstances and alerted the following train operators, thereby preventing all or most of these accidents.

On the day of the Graham Avenue accident, train operators were experiencing delays on the line because of heavy traffic. When the operator of a southbound train had stopped, he properly radioed the command center dispatcher, who contacted two other following trains and instructed them to stop. Shortly thereafter, the southbound train proceeded toward its next stop, which was Graham Avenue station.

Meanwhile, the northbound train, 1654L was stopped at the station. However, the train operator failed to radio the command center regarding a red indication at the signal. Moments later, another northbound train, 1658L, struck the rear of train 1654L.

The Safety Board believes that when used with the signal system, effective radio communications serve as an additional means of informing train operators about potential problems, and help to ensure safe train movement. Proper notification alerts train operators of the traffic conditions ahead, thereby providing them with

Table 7 — Rear-end Collisions on the NYCT System

Date	Location	Actions By The Operator On The Struck Train
07/26/90	S/O 9th Avenue	Stopped south of the 9th Avenue station due to congestion; did not call command center.
10/7/93	Graham Avenue	Stopped and held his train in Graham Avenue station 4 minutes because of delays; informed conductor of congestion; did not call command center.
02/9/95	Brooklyn	Stopped at red signal for 3 minutes; did not call command center.
06/5/95	Williamsburg Bridge	Twice stopped on red signals and slowly proceeded on yellow signals for about 3 minutes; did not call command center.

a greater opportunity to stop their trains. The Safety Board concludes that had the M train operator or one of the train operators ahead of him radioed the command center to report being stopped at the red signals, as they were required to do, and had the command center personnel relayed this information to the operator of the J train, he may been alerted in time to stop his train.

The confusion with and the failure to adhere to Rule 40 (m) of the NYCT employee operating manual raises some questions as to the effectiveness of the NYCT oversight procedures. As a result of its investigation of a February 9, 1995, accident in which an M line train struck the rear of a stopped B line train near the 9th Avenue station in Brooklyn, New York,[32] the Safety Board found that the NYCT lacked an effective program for ensuring operator compliance with operating rules. In that report, the Board observed that the NYCT had no unannounced oral or written compliance tests and made the following recommendation to the NYCT:

R-96-10

> Revise the Operating Employee Evaluation Check List to effectively determine compliance with operating rules and instructions and include, at a minimum, unannounced speed and signal tests and radio communication procedures. Provide standardized written instructions for administering and grading the evaluation check list.

On May 22, 1996, the NYCT responded that a lack of staff prevented the transit agency from conducting an optimal number of unannounced radar checks. The transit company reported that since June 1995, with additional staff, the RTO has conducted 5,800 tests systemwide and that the agency intended to continue that level of testing. It reported that its Office of System Safety had approved in January 31, 1996, an efficiency test program designed to monitor train operators' compliance with NYCT rules and regulations and that the NYCT was collecting and maintaining all information in a database that would enable the transit company to identify problems, correct them, and track employees' progress. The recommendation is currently classified "Open—Response Received."

An NYCT official testified that after the Williamsburg accident, the transit company increased the number of speed checks dramatically, which has resulted in a reduction in the number of violations. The Safety Board is pleased with the NYCT's efforts to improve its operators' compliance with speed restrictions, but points out that this is only part of the recommendation. The confusion about proper communications procedures among the operating personnel interviewed after this accident demonstrates that issuing bulletins does not ensure that employees understand and comply with operating rules and highlights the need for more extensive measures to improve compliance. The Board believes that the NYCT needs to ensure through training, retraining, and testing that its train operators understand and properly adhere to proper communication procedures, specifically Rule 40 (m) of the NYCT operating manual.

Adequacy of Signal Spacing for Braking

On June 5, 1995, the J train failed to stop within the block although the trip arm at signal J2-128 properly triggered the train's emergency brakes. From separate tests conducted by the Safety Board and by the NYCT and from surveys conducted by independent contractors, it was determined that most signal blocks in the NYCT system do not have adequate emergency braking distance. In the case of the Williamsburg Bridge approach, the distance between

[32]See Railroad Accident Report--*Collision and Derailment of Two Subway Trains, Metropolitan Transportation Authority/New York City Transit, in Brooklyn, New York, on February 9, 1995* (NTSB/RAR-96-01).

signals J2-128 and J2-125 was 270.35 feet. As train operators typically do on an incline, the J train operator probably had applied full throttle on the bridge approach and was traveling between 34-36 mph when the J train passed signal J2-128. Given the R-40 brake configuration and the train speed, the vehicle needed an emergency braking distance of about 300 feet. The Safety Board concludes that had the J train operator applied the emergency brake at the J2-128 signal, he would not have been able to stop his train before it entered the occupied block ahead, given the speed at which he was traveling.

During the March 5, 1996, postaccident braking tests conducted on dry rail, the stopping distances during emergency braking were shorter than during full-service braking at lower speeds. The stopping distances during full-service braking were shorter than emergency braking stopping distances only during tests conducted at 40 mph. However, the following day during wet rail conditions, the braking test results were significantly different. Full-service stopping distances were shorter than emergency stopping distances at all speeds. Further, the number and incidence of wheels locking up during the emergency braking increased at higher braking speeds on the wet rail.

Safety Board investigators determined that the lack of consistency in stopping distances was attributable to the brake cylinder pressure variances. After the Williamsburg Bridge accident, the NYCT attempted to decrease the stopping distance of the R-40 by adjusting the load sensor and variable load valve to increase the brake cylinder pressure to 30 psi +/- 2 for empty cars and to 40 psi +/- 3 for fully loaded cars. The Safety Board recognizes that this is the maximum adjustment that the NYCT can make, given the design of the R-40 braking system. However, the adjustment still can result in a pressure variance between cylinders of 4 psi when the cars are empty and 6 psi when the cars are full. Under wet rail conditions, such pressure variances can cause some wheels to slide during emergency braking while others continue to roll, resulting in inconsistent and extended braking distances.

In response to the tests and surveys, the NYCT has initiated a number of other changes in an effort to ensure that trains will stop within a block. For example, it has posted speed limits on the Williamsburg Bridge approach and other selected sites where the emergency braking distance is not sufficient for trains traveling at maximum attainable speed. The transit company has also retarded the acceleration capability of several of its newer, more powerful car models. Although the company intends to install computer-based signaling, which offers the most effective safeguard against operator error, on the entire NYCT system, this project will not be completed for 50 years.

The Safety Board acknowledges the efforts of the NYCT to improve its system but believes that these changes neither guarantee that an accident caused by operator error will not occur nor reflect everything that the NYCT can do to maximize safety.

The Safety Board considered a number of measures, which either alone or in combination with each other, would prevent rear-collisions on the NYCT signal system. For example, the Board has long been an advocate of train control systems and has included positive train separation (PTS) on its list of "Most Wanted Transportation Safety Improvements." The PTS system provides an automatic means of backing up the train operator's actions by monitoring the performance of operator and train when approaching the limits of a signal or speed restriction. Should the operator or the train fail to apply the proper brake action, the PTS system will assume control, automatically apply the brakes, and stop the train.

The Williamsburg Bridge accident marked the second time in 4 months that the automatic stop arm failed to prevent a rear-end collision on the NYCT system. In the February 9, 1995, accident in Brooklyn, the Safety Board found that the automatic stop arm did not prevent the striking train from entering a restricted block. As a result of its investigation of the Brooklyn accident, the Safety Board issued the following recommendation to the NYCT:

> R-96-11
>
> Include overspeed protection and positive train separation in the modernization of the signal system.

In a letter dated May 22, 1996, and in interviews conducted as part of the Williamsburg Bridge accident investigation, NYCT officials reported that the transit company is currently installing a pilot transponder project on the Rockaway line, which is scheduled to be completed by the end of 1997. A transponder is a digital radio device placed in the rail or on the wayside. When a train equipped with a companion device, called an interrogator, passes by the transponder, the mechanism provides information about the identification, location, and operating speed of the train. Should the train be traveling too fast for conditions and/or traffic, the transponder will cause the train to slow to the proper speed. Officials indicated that the transit company intends initially to use the Rockaway project to gather data in order to determine the feasibility of installing transponders in other areas of the NYCT system.

The Safety Board is pleased that the NYCT is taking positive action on this recommendation. However, the transponder project is a future program that is limited in scope, which does not solve the NYCT's immediate systemwide problem of not being able to prevent rear-end collisions caused by operator error. Moreover, the Safety Board believes that a number of changes could now be made to the NYCT signal system to prevent such accidents, including some of the following measures:

- Remove and/or respace signals;
- Lengthen the control line;
- Set speed limits; and
- Convert automatic signals to grade time signals.

In a properly designed signal system with ATS, the wayside signals are so spaced that when a train traveling at maximum speed passes a red signal, the vehicle is brought to a stop within the block after having its emergency braking tripped. Throughout the NYCT system, the spacing between automatic signals does not provide sufficient emergency braking distance for most NYCT trains traveling at maximum attainable speed. Were the NYCT to remove every other signal and/or resite wayside signals, it could provide the distance needed for emergency braking. If the transit company was concerned about the costs of resiting the signals, it could achieve longer blocks and consequently greater stopping distance by deactivating every other signal.

Another way to ensure that a trailing train will not strike the train ahead of it is to increase the length of the control line. The NYCT generally uses a two-block control line in wayside areas, in which the signals in two blocks display a red stop indication. The wayside automatic stop arm is in the upright trigger position only in the first restricted block. Were the NYCT to increase its control line to three blocks, an errant vehicle traveling at fast speed would have the distance in two blocks for emergency stopping. The NYCT could program the automatic stop arms in the first two blocks to be in the upright position when their companion signals were red for an extra margin of safety.

The NYCT could impose additional speed restrictions to improve safe transit. After the Williamsburg Bridge accident, the transit company posted speed signs in selected areas. This measure does not keep train handlers from operating as fast as the train can travel in other areas, which requires them to make adjustments when they encounter trains that are slowing for traffic or stations ahead. Were the NYCT to impose a lower maximum speed limit on its entire system, it might somewhat eliminate the tendency of vehicles on a line to bunch.

Regardless of whether the NYCT does or does not establish a maximum speed limit on its entire system, the Safety Board believes that the transit company should change its operating rules governing movement under *approach* signal aspects. The employee operating manual at Rule 59 (b) indicates that upon encountering a yellow signal aspect, the train operator is to "Proceed with caution, be prepared to stop." The manual does not stipulate that a train operator should slow down or should not exceed a given speed when operating under a yellow aspect. As a result, train operators can operate at maximum speed when under a caution indication. The Safety Board believes that the NYCT should change its operating rules to restrict train movement under a yellow aspect to a specific maximum speed that is appropriate for all rail conditions.

Another method of controlling train speed and thereby making the signal system design safer is to convert automatic signals to time signals. Most of the NYCT system is wired for automatic movement. An automatic signal displays a restrictive indication only when the block ahead is occupied. In an automatic signal system, therefore, if train operators have no trains ahead of them, all signals will be green, and they can move as fast as their trains are capable of traveling. In a system using time signals, block signals display restricted indications that clear to yellow or green after a specified time period as trains approach. Time signals serve to enforce a speed limit because a train operator who is traveling faster than the programmed time (the established speed limit for an area) and who enters a block before its signal clears risks tripping the automatic stop arm, which will activate the train's emergency braking.

The NYCT officials characterize their system as safe when their train operators comply with the operating rules. The Safety Board strongly believes that the NYCT's practice of relying on operator compliance to ensure the safety on its system is not adequate. Too many factors at and/or outside the workplace can affect human performance. In the Williamsburg Bridge accident, 1 person was killed and 64 people sustained injuries requiring treatment at area hospitals. Other people on board the two trains were injured but elected to be treated on scene by medics rather than go to the hospital. In the 5 years before this accident, the NYCT had seven operator-error accidents in which a total of 5 people were killed and more than 300 people were injured. The Safety Board concludes that the current design of the NYCT signal system does not provide sufficient safeguards against accidents caused by operator error. Accordingly, the Safety Board believes that the NYCT needs to identify those areas on its system that do not have sufficient braking distance for trains traveling at maximum attainable speed and enact changes that will ensure rear-end collisions will be prevented.

Crashworthiness

In this accident, the J train was traveling on tangent track at an estimated speed of 18 mph when it struck the M train. Collision forces on tangent track are substantially linear and normally absorbed into the carbody end-structures, resulting in compressive collapse and crush zone intrusion. In both type cars, the end and corner posts successfully minimized carbody telescoping and resisted progressive crush as the posts pulled the roof and floor structures together in an inward folding action.

During postaccident examination of the wreckage, Safety Board investigators noted that the rear car of the M train, 4664, had raised and separated from its truck assembly such that it was elevated slightly above the anti-climber of the J train's lead car, 4461. Further, the J train's lead car had telescoped slightly into car 4664. During a rear-end impact, the anti-climbers on the vehicles should lock in place and prevent one car from penetrating, or telescoping, into the other. When anti-climbers fail and telescoping does occur, typically the amount of body crush to the accident vehicles is disproportionate. In this accident, the amount of carbody crush to units 4664 and 4461 was progressive, about equal, and limited to the ends making contact, meaning that the anti-climbers did not completely fail, but that the structural strength of their flanges was exceeded because of the comparatively high impact forces that were exerted on the carbody end structures. The Safety Board concludes that the carbody-end structure was sufficiently effective, given the estimated collision speed and the amount of telescoping damage.

On the M train, 12 passengers and 2 crew-members suffered minor injuries typical of the types sustained by standing people when they are thrown to the floor and by seated people when they are pitched rearward against hard obstacles during a low-speed, rear-impact collision. No one was in the intrusion crush zone at the time of impact.

On the J train, the train operator was fatally injured as a result of the intrusion of the M train carbody, which totally crushed the operator cab, leaving no survival space. Two passengers standing behind the operator's cab, where collision forces were higher, sustained serious injuries. A total of 50 passengers suffered minor injuries and/or lacerations typically sustained by people when they strike hard surfaces or sharp objects.

Emergency Response

The accident was reported to the police 911 dispatcher at 6:17 a.m., 5 minutes after the collision occurred. Rescue units were on scene by 6:22 a.m. and the first life support ambulance arrived shortly thereafter. Transit company personnel were readily able to usher passengers who were not injured or who did not have serious injuries from the cars. Moreover, responders were readily able to extricate the more seriously injured from the vehicles. A total of 47 ambulances and a transit bus were used to transport the 55 injured to 11 area hospitals. The Safety Board concludes that local emergency response personnel reacted promptly to and acted effectively at the accident site. Further, the design of the NYCT cars provides sufficient egress in the event of an emergency.

Adequacy of PTSB Oversight

The Safety Board has long advocated that oversight responsibility properly resides with the State and local authorities and has pointed to the New York State PTSB as a model program. The Board is concerned, however, that PTSB may not have sufficient resources to oversee the large, old, and complex system of the NYCT. Because the FTA has completed its rulemaking on State oversight, the Safety Board has corresponded with each State in which a rail rapid transit system operates to determine how the intent of the FTA's rulemaking will be accomplished. The Safety Board will follow up with the State of New York in Safety Recommendation R-91-37 to determine if the PTSB has sufficient resources to fulfill its mandate.

CONCLUSIONS

Findings

1. Factors related to the weather, the train equipment, the track, and the operation of the signal system neither caused or contributed to the accident. Toxicological tests for alcohol and drugs were negative. The operator of the J train was in good health and was an experienced and qualified NYCT train handler.

2. The J train operator failed to take action to stop his train on the Williamsburg Bridge because he was asleep.

3. The NYCT operating manual at Rule 40 (m), which stipulates that train operators must immediately notify the command center when they are stopped at red signals, is often misinterpreted by employees and is therefore inconsistent with NYCT's actual mode of operation.

4. Had the M train operator or one of the train operators ahead of him radioed the command center to report being stopped at the red signals as they were required to do, and had the command center personnel relayed this information to the operator of the J train, he may been alerted in time to stop his train.

5. Had the J train operator applied the emergency brake at the J2-128 signal, he would not have been able to stop his train before it entered the occupied block ahead, given the speed at which he was traveling.

6. The current design of the NYCT signal system does not provide sufficient safeguards against accidents caused by operator error.

7. The effectiveness of the carbody-end structure post was reasonable, given the estimated collision speed and the amount of telescoping damage.

8. Local emergency response personnel reacted promptly to and acted effectively at the accident site.

9. The design of the NYCT cars provides sufficient egress in the event of an emergency.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the J train operator to comply with the stop indication because he was asleep and the failure of the train to stop within the block because of inadequate braking distance between signals on the Williamsburg Bridge. Contributing to the accident were the New York City Transit's inadequate measures for ensuring employee compliance with proper radio procedures.

RECOMMENDATIONS

To the Federal Transit Administration:

In cooperation with the American Public Transit Association, develop a fatigue educational awareness program and distribute it to transit agencies to use in their fitness-for-duty training for supervisors and employees involved in safety-sensitive positions. (Class II, Priority Action) (R-96-20)

To the American Public Transit Association:

Assist the Federal Transit Administration in developing a fatigue educational awareness program for transit agencies to use in their fitness-for-duty training for supervisors and employees involved in safety-sensitive positions. (Class II, Priority Action) (R-96-21)

To New York City Transit:

Develop and disseminate a training and education module to inform train operators and other employees involved in safety-sensitive positions about the hazards of performing their duties while fatigued. (Class II, Priority Action) (R-96-22)

Clarify Rule 40 (m) to ensure that the requirement for train operators to notify the command center when they are stopped at a red signal is independent of the procedures for keying by a red signal. (Class II, Priority Action) (R-96-23)

Ensure through training, retraining, and testing that employees understand and consistently adhere to the operating procedure at Rule 40 (m) requiring that they immediately contact the command center when they stop their train at a red automatic signal. (Class II, Priority Action) (R-96-24)

Identify those areas on your system that have insufficient braking distance for trains traveling at maximum attainable speed and implement appropriate changes to prevent rear-end collisions caused by operator error. (Class II, Priority Action) (R-96-25)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Chairman

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Vice Chairman

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Member

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Member

September 4, 1996

APPENDIX A

Investigation and Hearing

The Safety Board was notified by New York City Transit at 9 a.m. on June 5, 1995, of a rear-end collision between two of its subway trains on the Williamsburg Bridge in Brooklyn, New York. The Board launched a major railroad accident investigation team, which was accompanied by Board Chairman Jim Hall and a representative of public affairs. The on-scene team formed groups to investigate the track, signals, operations, mechanical, human performance, and survival factors.

The Office of the Inspector General (MTA), New York State Public Transportation Safety Board, New York City Transit, New York City Transit Police, New York City Fire Department, New York City Police Department, and the New York City Emergency Medical Service assisted in the Safety Board investigation

As part of its investigation, the Safety Board held a 2-day public hearing at the Borough of Manhattan Community College in New York City, New York, on November 29-30, 1995. Parties to the hearing included the Federal Transit Administration, the New York City Transit, the New York State Public Transportation Safety Board, the American Public Transit Association, and the Transit Workers Union of America AFL-CIO. Twelve witnesses testified.

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APPENDIX B

Personnel Information

J Train Conductor — The J train conductor, 45, began work with the NYCT as a conductor in 1979. He passed his last periodic medical examination on September 8, 1994. He had 21 records in the Division of Rapid Transit Operations Disciplinary Action History database. During the last 5 years, he had three cases of disciplinary action pertaining to administrative violations, including undocumented emergency, absent-without-leave (AWOL), and late report.

M Train Operator — The operator of the M train, 31, was hired as a conductor by the NYCT on November 21, 1988. He passed his last medical examination on January 19, 1995. His last operating employee evaluation, which was conducted on February 2, 1995, shows that he was rated "good" on the majority of the evaluation check list items and "acceptable" on the rest of the items. His personnel file contained four cases of disciplinary action for administrative violations for such infractions as AWOL, Sick and not home, and no doctor lines; he had not received any disciplinary actions for violations of operating rules.

M Train Conductor — The conductor of the M train, 39, was hired by NYCT as a conductor in September 1992. He passed his last medical examination on July 25, 1994. His last operating employee evaluation, which was conducted on May 2, 1994, shows that he was rated "good" on all check list items. He had no records in the Division of Rapid Transit Operations "Disciplinary Action History" database. He reported for his regular assignment on June 5, 1995, at 5:33 a.m. at the Metropolitan Avenue station.

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APPENDIX C

NYCT Bulletin Number 17:93

NEW YORK CITY TRANSIT AUTHORITY
RAPID TRANSIT OPERATIONS

ON-THE-JOB
OFF-THE-JOB
Take SAFETY with You

BULLETIN

BULLETIN NO.: 17:93 March 4, 1993

TO: ALL EMPLOYEES

SUBJECT: **RULE 40(M): RED AUTOMATIC SIGNALS**

The text of Rule 40(m), concerning "Red Automatic Signals," in the 1992 revision of the NYCTA Rules and Regulations is changed to read as shown below. All employees should correct the last paragraph of this rule in their copy of the rule book.

Rule 40(m) A Train Operator must STOP for a RED Automatic Signal.

He/she must stop fifteen (15) feet short of the signal, or at the yellow joint marker plate on the contract rail protection board. He/she must NOT MOVE until the light turns to YELLOW or GREEN, UNLESS:

1. The signal has an "AK" sign; or
2. The signal is on a storage track or in a yard; or
3. An employee whom the Train Operator KNOWS is an authorized RTO or Electrical (Signal) employee gives a signal to go ahead which the Train Operator KNOWS is meant for him/her; or
4. The Train Operator calls the Command Center Desk Superintendent by radio and is told to proceed with RESTRICTED SPEED AND EXTREME CAUTION

The Train Operator must call the Command Center Desk Superintendent immediately via radio. If Command Center does not acknowledge the transmission and there is no train visible ahead, he/she must wait two (2) minutes before using the wayside telephone. If after ten (10) minutes and there is a train visible ahead and Command Center still has not acknowledged the radio transmission, the Train Operator must then use the nearest wayside telephone.

Nathaniel Ford
Chief Transportation Officer
Rapid Transit Operations

Photocopy is 80 percent of actual size.

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APPENDIX D

NYCT B Form
Operating Employee Evaluation Check Lists

The form on the next page is the evaluation check list that NYCT supervisors were using at the time of the Williamsburg Bridge accident. As a result of a February 9, 1995, accident in which an M line train struck the rear of a stopped B line train near the 9th Avenue station in Brooklyn, the NYCT revised the format of B Form, adding specific performance requirements under the more general categories. The revised evaluation form follows the earlier version.

NEW YORK CITY TRANSIT AUTHORITY
RAPID TRANSIT OPERATIONS DEPARTMENT

OPERATING EMPLOYEE EVALUATION CHECK LIST

NAME ______________________________ PASS ___________ TITLE ________

DATE __________ TIME ________ DIVISION ________ DIRECTION ___________

CAR NO. ___________ INTERVAL/LINE/TERMINAL _____________________________

JOB NO. __________ REGULAR JOB NO. ______________________ RDO _________

YEARS IN TITLE ____________ BRAKE VALVE HANDLE NO. ____________________

WEARING SAFETY GLASSES? YES NO

PRESCRIPTION GLASSES REQUIRED? YES NO

WEARING PRESCRIPTION GLASSES? YES NO N/A

CONDUCTOR	CODE	TRAIN OPERATOR
UNIFORM	___	UNIFORM
APPEARANCE	___	APPEARANCE
SAFETY EQUIPMENT	___	SAFETY EQUIPMENT
P.A. CHECK AT TERMINAL	___	P.A. CHECK AT TERMINAL
USE OF PUBLIC ADDRESS	___	USE OF PUBLIC ADDRESS
COMMUNICATIONS BOOK	___	COMMUNICATIONS BOOK
USE OF RADIO	___	USE OF RADIO
KNOWLEDGE OF RUNNING TIME	___	KNOWLEDGE OF RUNNING TIME
BOARDING TRAIN AT TERMINAL	___	BOARDING TRAIN AT TERMINAL
CAB DOOR POSITION	___	CAB DOOR POSITION
SIDE SIGNS	___	SIDE AND END SIGNS
DOOR OPERATION	___	BRAKE TESTS: STANDING, ROLLING, RUNNING
OBSERVING PLATFORM	___	JUDGMENT OF SPEED AND DISTANCE
PLATFORM DUTIES	___	STATION STOPS
FLAGGING DUTIES	___	REACTION TO SIGNALS
PASSENGER RELATIONS	___	SPEED OVER SWITCHES
	___	PROPER OPERATION, PASSENGER SERVICE
	___	PROPER OPERATION, YARD/LAY UP TRACKS
OVERALL OPERATION	___	OVERALL OPERATION

MARK WITH APPROPRIATE CODE: GOOD (G), ACCEPTABLE (A), UNACCEPTABLE (U)

REMARKS ____

____

____

REPORTED BY ____
(TITLE) (NAME) (PASS)

ORIGINAL TO LINE SUPERINTENDENT, COPY TO EMPLOYEE

MTA NEW YORK CITY TRANSIT—RAPID TRANSIT OPERATIONS

OPERATING EMPLOYEE EVALUATION CHECKLIST—B FORM

MARKING INSTRUCTIONS
- Use a No. 2 pencil or blue or black ink pen only.
- CORRECT MARK ●
- INCORRECT MARKS

JOB NO. | DATE (MO, DAY, YR) | INTERVAL | LOCATION

TIME | CAR

PASS NO | TSS PASS NO.

OVERALL

ALL EMPLOYEES (Yes / No)

- ALL EQUIPMENTS
- FIT FOR DUTY
- PROPER UNIFORM
- UNIFORM NEAT/CLEAN
- PRESCRIPTION GLASSES REQUIRED
- WEARING PRESCRIPTION GLASSES
- WEARING SAFETY GLASSES
- WEARING HEARING PROTECTORS
- SAFETY EQUIPMENT: VEST/FLASHLIGHT
- RULE BOOK
- BLUE BOOK

OPERATION READINESS (Yes / No)

- REPORT ON TIME
- CHECK BULLETIN BOARD
- BOARD TRAIN ON TIME
- RADIO CHECK
- SIDE/END SIGN CHECK
- KNOWLEDGE INTERVAL/RUNNING TIME
- PROPER CAB DOOR POSITION

TRAIN OPERATORS ONLY

T/O OPERATIONS (G / M / U)

- BRAKE TEST: STANDING/ROLLING/RUNNING
- STATION STOPS: SMOOTH/ACCURATE
- UNDERSTAND SIGNAL/MISC. SIGNS
- JUDGMENT OF SPEED
- BRAKING/DISTANCE JUDGMENT
- OPERATION OVER SWITCHES
- OPERATION IN LIMITED AREAS
- OPERATION IN GENERAL ORDER AREAS
- UNDERSTAND FLAGGING
- KNOWLEDGE OF BUZZER/HORN SIGNALS
- PROPER OPERATION CUSTOMER SERVICE
- PREPARING TRAIN FOR SERVICE
- SPEED IN YARD/STORAGE AREAS
- OPERATIONS IN/OUT OF BARN
- SAFETY STOPS
- COUPLING AND UNCOUPLING
- UNDERSTAND DOOR OPERATIONS
- BREAKDOWN FAMILIARIZATION
- OTHER [illegible] OPERATIONS
- RADIO COMMUNICATIONS
- P/A ANNOUNCEMENTS

CONDUCTORS ONLY

CONDUCTOR OPERATION (G / M / U)

- PROPER DOOR OPENING
- PROPER DOOR CLOSING
- PROPER PLATFORM OBSERVATION
- RADIO COMMUNICATIONS
- KNOWLEDGE BUZZER/HORN SIGNALS
- CUSTOMER RELATIONS
- ASSIST: DETRAINING/ENTRAINING
- ASSIST TRAIN CREWS CLOSING
- IN PROPER POSITION ON PLATFORM
- ASSIST WITH L/U AND P/I AT TERMINAL

P/A ANNOUNCEMENTS (Yes / No)

- STATION IDENTIFICATION
- TRANSFER OPTIONS
- TRAIN IDENTIFICATION
- TERMINAL BOROUGH DIRECTION
- NEXT STOP
- STAND CLEAR CLOSING DOOR
- CONDUCTOR SPEAKING SLOWLY ENOUGH TO BE EASILY UNDERSTOOD
- DURING DELAYS DID CONDUCTOR MAKE TIMELY ANNOUNCEMENTS
- DID CONDUCTOR MAKE ANY NON POLICY ANNOUNCEMENTS

CONSTRUCTION FLAGGER (Yes / No)

- CAUTION LAMPS/FLAGS IN PROPER LOCATION?
- FLAGGER AND PORTABLE TRIP IN PROPER PLACE?
- DOES FLAGGER HAVE PROPER LAMPS/FLAGS?
- DOES FLAGGER HAVE PROPER SAFETY EQUIPMENT?
- DOES FLAGGER ENSURE THAT WORKMEN ARE CLEAR OF TRACKS?
- ARE CORRECT FLAGGING SIGNALS BEING GIVEN?
- IS FLAGGER FAMILIAR WITH WORK LOCATION?
- DOES FLAGGER UNDERSTAND FLAGGING RULES AND REGULATIONS?
- IS FOREMAN SATISFIED WITH FLAGGER?

COMMENTS

Photocopy is 80 percent of actual size.