New York City Transit's Efforts Towards Central Control: A Progress Report

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1 CENTRAL MONITORING HISTORY

New York City Transit (NYCT) began the process of centralizing control in the 1950's. Individual interlockings were tied together into groupings in the master towers and the process was slated to continue all the way to a single master tower, the Control Center. Unfortunately, the business cycle plays large role on infrastructure, and these efforts stalled during the city's financial crisis of the 1970's.

With the implementation of the Subways Capital Program in 1984, NYCT began a process of rehabilitating interlockings on the IRT until a State of Good Repair was reached in the 1990's.

Some high profile incidents moved the agency to bring in industry experts, and their conclusion was that NYCT needed central monitoring and control to effectively move our 6,000,000 passengers per day. At the time of this study, NYCT had a simple Command Center with radio and telephone communication to field crews, and a rudimentary train location system on the IRT. As we will see, we are in the final design phase of full central control for the entire system and want to provide an update on our progress, our lessons learned, and some of the concepts the project team has developed.

2 INCREMENTAL CENTRALIZATION

Provided below is a summation of recent past, and future steps NYCT has taken to the ultimate goal of full central monitoring and control. These steps offer views into contrasting methods of data capture, from the traditional contractor/engineer driven mega-project to the small homegrown applications developed rapidly by small teams. By comparing the methods we see a pattern emerge over time. Central monitoring and control is an effort that can increasingly be initiated by in-house forces at a lower cost, while contractor work can focus on integration.

2.1 ATS-A

New York City Transit took its first steps to centralization and control with the procurement of Automatic Train Supervision-A Division (ATS-A) in 1995. Commercial and contractor issues delayed the project in its infancy and the system was finally completed in 2005 by Siemens Transport Systems. This train monitoring and control application was designed in coordination with the movement of central incident handling from 370 Jay St. to the newly constructed Rail Control Center (RCC).

ATS-A consisted of central monitoring and control of the IRT 1 through 6 lines. The program to bring all NYCT interlockings into a state of good repair was completed first in the IRT, with all Master Towers converted to NX interlocking machines. The 'center return' nature of the NX pushbuttons allowed the signal contractor to install Primary Logic Controllers (PLC) in all relay rooms, therefore digitizing the indications and relay control logic and importing it to the RCC. As an example of the challenges associated with upgrading a system on the scale of NYCT, the White Plains and Dyre lines were still undergoing necessary signal rehabilitations at the time of ATS-A Beneficial Use. These 'dark territories' are only scheduled to come on-line in the end of 2013.

Train tracking and interlocking control, coupled with the fact that all operating departments were now housed under one roof provided immediate benefits and challenges. Multi-divisional response to major incidents, coupled with the ability to monitor and control service centrally, lead to increased efficiency in incident handling. The challenge, however, was the fact that operators were given hundreds of new functions and abilities in one 'big bang' system, and managing the operational readiness for a system as large as ATS-A was not on NYCT's radar in the rush to complete the project. These issues will be discussed in greater detail in later sections.

2.2 CBTC

As part of its ongoing subway modernization program, NYCT is in the process of upgrading its signal system from one based on fixed block, wayside signals/trip stop technology to Communications-Based Train Control (CBTC) technology, utilizing two-way digital RF communications between intelligent trains, and a network of distributed wayside zone controllers. The Canarsie Line is the first NYCT line to be equipped with CBTC technology. The next line will be the Flushing, No.7 Line which is under design.

NYCT's conventional signaling system relies upon track circuits to detect the presence of trains. Information on the status of the track ahead is provided to train operators through wayside signals. The signaling system safety is ensured through wayside trip stops. This system, and all other signal systems based on similar technology have a number of limitations: The location of trains is only as accurate as the track circuit layout, track circuits can be made shorter, but each additional track circuit requires additional wayside hardware that has a cost and lower overall reliability, and the information that can be provided to a train is limited to a small number of wayside signal aspects.

The automatic train stops provide only intermittent enforcement; trains can accelerate between signals and trip stops. CBTC improves train control capabilities by means of high accuracy of train location which is independent of track circuits. CBTC also provides a continuous train-to-wayside and wayside-to-train wireless data communications network to permit the transfer of large amounts of control and status information. Wayside and carborne vital computers process the train status and control data and provide continuous train protection.

Under CBTC operation movements in both directions on all tracks and head-to-head moves for shuttle operations are allowed and fully signal protected. The system also enforces temporary speed restrictions on the track from the Rail Control Center and enforces work zones to ensure trains are warned and speed is reduced when personnel are working on or about the tracks.

With high accuracy of train position detection, CBTC allows trains to operate safely at shorter headways and permits system operations to recover more rapidly in the event of a delay—all of which provides more regular and improved passenger service. Shorter headway translates directly to increased line capacity, enabling increases in ridership.

The project was piloted on the Canarsie Line and will expand to the Flushing line for the express reason that these lines are the only areas in NYCT's network that do not mix multiple services. Lessons learned from dedicated line projects around the world would also apply to the L and 7. The challenge comes when NYCT seeks to expand beyond the pilot lines. The next projected CBTC project is Queens Boulevard Line (QBL) which services the N, R, M, and F. Since there is a wayside and carborne aspect to the signaling system NYCT will have to outfit multiple fleets at a time for each small area or CBTC control.

2.3 I-Trac

On the B-Divison, all train movement is currently recorded on paper and shipped to a central location for processing, statistics generation and storage. With no immediate central monitoring system in sight, Technology and Information Services (TIS), in conjunction with Rapid Transit Operations (RTO), started development on the Integrated Train Activity Console (I-TRAC) project. I-Trac is a web-based application that computerizes all dispatcher train movement recording functions, and integrates directly with the Subway Train and Reporting System (STARS) creating a combined platform that will automatically provide real-time service performance indicators such as: Schedule Adherence, On Time Performance, Thru-put, Wait-Assessment, Mileage, and Mean Distance Between Failures. I-TRAC utilizes user-friendly interfaces in addition to receiving data directly from systems such as: Unified Timekeeping System, Car Consist application, Electronic Schedules, and ATS-A to minimize errors and eliminate redundancies. I-TRAC has been successfully implemented on the #7 Line replacing the Subways Train and Traffic Information System (STATIS) system. The software is currently being rolled out across the B-Division starting with the B/D lines and the entire division by 4Q 2013. The software also includes Lay-up/Put-in and yard functions that integrate Car Equipment and Yard Dispatcher functions to streamline maintenance in barns.

The homebrew nature of the software does come with benefits and challenges. NYCT owns the source code and can manipulate the system in any way necessary to adjust to changing requirements for statistical generation and operating policy changes. Unlike a capital project let out to a contractor, however, NYCT absorbs 100% of the risk associated with a venture of this magnitude.

2.4 PLC Project

In response to the repeated failure of an Automatic Train Supervision – B Division (ATS-B) to receive funding, again due to the perturbations of the business cycle, an internal NYCT group Maintenance of Way/New Tech Signals (NTS) has begun the process of installing PLCs in B-Division towers to capture train movement indications. Portions of the Flushing, Astoria, West End, Sea Beach and 8th Ave lines are processed through the PLCs and imported into the RCC through an internally developed user interface.

This project provides the first new train movement indications in the RCC since the ATS-A and CBTC-Canarsie projects completed in 2005. NYCT is in the process of using these indications to manage service regularity and incident handling in areas where these roles could only be performed by personnel in the Master Towers. Being that these are train movement indications only, RTO is able to take an incremental approach to service monitoring on the B-Division, one that was impossible with the all-at-once nature of the ATS-A project.

A pilot program, to provide train arrival information from the PLCs installed on the Flushing line directly into I-Trac was completed in 2012. The interface is currently one way and therefore does not have the robustness of a bi-directional interface, but does prove the concept that automatic train arrival information for reporting and customer information is possible and relatively inexpensive in today's environment.

2.5 ISIM-B

As previously stated, the advancement of ATS-B has fallen victim to the business cycle multiple times. Efforts in 2006, 2008, and 2010 failed due to lack of funding. However, an interesting dynamic developed in response to the ATS-A system's ability to make predictive train arrival announcements on platforms through Countdown Clocks as a part of the Public Address – Customer Information Signs (PA-CIS) system. A customer driven campaign, filtered through city and state governmental representatives, demanded that the train arrival signs on the 1 through 6 lines be made available to all NYCT customers. Based upon this pressure, the agency committed to providing predictive train arrival information to the customers on the platform and on the web by 2017.

From these discussions RTO was able to make the case that only a fully automatic train monitoring and identification control system would provide the necessary data robustness to drive Countdown Clocks. Thus the Integrated Service Information and Management – B Division (ISIM-B) system was approved for design by the MTA Board.

ISIM-B is not a system in the strictest sense, but an umbrella project that seeks to integrate a monitoring and control office system, a customer information component, a data gathering and distribution system, and web enabled displays both in the RCC and off-site locations.

While still in the alternatives analysis phase of the project lifecycle, ISIM-B must at a minimum, provide train location and identification to the RCC while driving customer information systems across the B-Division. A major challenge of this project is its eventual integration/interface with future CBTC control projects. RTO is insistent on a single user-facing interface, so ISIM-B must be given complete control capability over CBTC territories, or more simply, is an extended office system for the entire division as part of the CBTC ATS future packages.

Regardless of the outcome of the selection of the underlying technologies, ISIM-B will conform to strict standards as outlined by RTO, the end user. Lessons learned from ATS-A and CBTC, discussed further in later sections, will be instrumental in any development process.

3 MAINTAINING OPERATIONAL EFFECTIVENESS

From the 'big-bang' projects, to the small homebrewed application, the operating departments must remain cognizant of their core business functions, and their preservation in the face of advancing technology. Moore's Law states that the number of transistors on a microcircuit doubles every two years. The challenge to operations is that employee skill sets, decision making, and operational readiness do not grow at the same rate as computer processing power. It is the challenge of the user representative on the design team to incorporate the maximum number of new and useful functions while maintaining the integrity of existing operational workflows.

3.1 Continuity of Operations

Transit, as with all safety sensitive industries is driven predominantly by rules, regulations, and procedures. For the first one hundred years of NYCT's existence, the march of technology was reasonably slow enough to adequately prepare for advancements. With the accelerated pace of technological tools, however, the capabilities of systems are far ahead of any organization's ability to predict and manage these changes.

Transit systems are also typically top-down hierarchies, and therefore the predominant opinion is that these rules and procedures were created by fiat some time in the distant past. In actuality, most policies and procedures, and certainly all workflows, developed organically over time. A mistake in 1943 leads to a procedure in 1944 and the operational workforce adapts. Understanding this type of unplanned development is critical in the design of centralized control systems. Designers must take extra caution to preserve as much of the existing operations workflow, while designing tools that are ostensibly sold as automatic replacements for manual processes.

The underlying task of the operator, however, remains the same, and operating departments must remain vigilant in preserving the aspects of the operation that are essential to continue to provide service. Not all functions are created equal, so operator representatives must identify the most commonly performed tasks in the manual environment, and either design full automation into the process or simplify the function to the point of being a routine task. It does not matter how well the relay logic is replicated in an office system if the task of marking a Train Operator out sick requires four dialogs and twelve mouse actions.

The 80/20 principal applies in transit operations at the same rate it does in nature and the private sector. 20% of your incidents causes 80% of your delays, 80% of your infractions are caused by 20% of your operators (and customers, for that matter). In this same vein 20% of your failure and incident control strategies are utilized 80% of the time. It is the design of this 20% that becomes critical. The challenge is to identify these strategies, and then design them into a system where the simplicity of initiating them is the same as verbally ordering a subordinate to perform an action.

This is an important point, because the difficulty of using computerized, automated systems is typically assigned to complexity or training requirements or user interface issues. In actuality the issue is one of language. As discussed before, the operations workflows and user actions in the manual environment grew organically, as did the shorthand language supervisors use to indicate a desired result from a manual operator. In ATS type systems, the manual operator is replaced by the computer, but the language used in requesting a task is not preserved. The simple task of saying 'Reroute all the 5s over the West Side" is replaced by a series of specific signal control actions, complex dialog based rerouting commands, and tabular adjustments to operating schedules.

If the designer can correctly identify the commonly occurring restorative actions, then any system can be programmed to 'memorize' the steps that need to be taken to perform the action. In order to maintain the integrity of operations and the workload of operators a full scale study of the finite number of failures that can occur, and the actions normally taken to recover from those failures must be identified, cataloged, and programmed into the centralized monitoring system.

This effort falls squarely on the operating departments, who must first fully understand their operations and business practices, document all of the variables, and monitor system designers, not only for compliance in programming these practices, but simplifying their triggers to the point where it is no more complex than giving an order to a subordinate.

3.2 Institutional Memory

An important concept in the private sector, institutional memory is the skills, experiences, and knowledge of a business group. Companies are concerned with this concept because of high turnover and the cost effectiveness of dealing with a rarely occurring problem with the same competency as common occurrences.

The concept was not as paramount in the transit environment because in the operating departments, the employee's experiences were their skills, and there was always an experienced worker in line to replace a departing one. Low turnover for public agencies helped facilitate this assembly line of competence.

Centralization of control in a complex system such as NYCT's can wreck havoc with institutional memory. Skills and knowledge that existed locally in field towers are not automatically transferred to the smaller group of central control operators. In a system where all equipment is uniform and there are no site-specific variations to the monitoring and control process this is less of a problem. But, in NYCT where the site specific signal and service arrangements far outweigh the typical, a thorough knowledge of the entire system is required to operate effectively.

In order to operate a tower machine in the manual environment, a Tower Operator trainee posts with an experienced Tower Operator for weeks before being allowed to work alone. During these weeks the trainee learns the incongruities of the individual machine, the normal and atypical service adjustments, what signal moves to avoid at what times of day, and absorbs the institutional memory of their trainer, who may have useful information on dealing with rarely occurring, but serious failures.

In order to preserve this knowledge transfer the RCC would have to perform one of two actions. The first would be to post every central control operator at all 144 B-Division interlockings for the two week period, which amounts to five and a half years of training. The second option is to design the institutional memory into the central control system.

All transit systems desire a knowledge base, whether in the form of comprehensive training documents, or call center-like decision trees to deal with incidents. Very few agencies have succeeded in this development. It is critical, therefore, to institutionalize a massive knowledge transfer in conjunction with a centralized control system. By documenting all the site-specific issues affecting train service, programming them into a system, and providing the operator with simple, common language feedback to their attempted control actions you have preserved institutional memory for the life of the system. This also mitigates the stresses of transitioning to central monitoring and control.

The effort, once again, falls on the operating department to fully categorize all site-specific information, through extensive interviews with experienced field personnel. The designer then must take the lead in the design team's efforts to provide a system that makes every user as knowledgeable as, in most situations, the system's most experienced employees.

3.3 Dynamic Nature of the Workforce

Economic trends are a recurring theme in our study of NYCT's centralized control efforts. The dynamic nature of the workforce in NYCT and its affect on central control design is driven both by economics and demographics.

In the wake of the New York City financial crisis of the 1970's, NYCT deferred hiring to meet with tighter fiscal policy. This trend began to reverse itself in the late 70's and early 80's with massive amounts of new hires brought in to fill systemic vacancies caused by a four year hiring freeze ending in 1977. The beginning of the Capital Program in 1984 also necessitated a large hiring pool into 1983.

This massive influx of new employees guaranteed a level of proficiency and experience for decades to come. Mid-Level and Senior management vacancies would be filled by this baby boom generation of experienced workers through the 21st century.

The issue arises that this large pool of experienced employees has been the backbone of NYCT's operation experience for upwards of 36 years as of 2013. With a massive influx of employees between 1977 and 1983 comes a similarly large wave of attrition between 2008 and 2013.

In addition, the state of disrepair that these baby boomers encountered in 1977 provided valuable operating and maintenance experience that would be utilized through the State of Good Repair efforts currently occurring today. In short, the institutional memory of this cohort is massive. Today there is a large portion of supervisory and management titles that have experience with every failure possible, coupled with a smaller, younger group who have enjoyed the fruits of the early 80's efforts to eliminate failures.

There is a brain drain occurring at an alarming rate. While organizationally there are succession planning methods and management readiness training, in an operating department, where your experience is your skill, these are not as effective. Signal maintainers can be hired from the general population of workers with electrical and mechanical backgrounds, but there are very few potential employees on the street that have experience operating a heavy rail transit system.

Again, the concept of user driven design is one of the most promising solutions. In previous sections we discussed capturing and codifying the institutional memory for the purpose of providing productive feedback to all employees. Here we must design with the fact in mind that during the life cycle of any system we institute, the experience level and competency of the operators will drop precipitously over time. This competency level reduction is in addition to the normal level of aptitude reduction that occurs when you remove the employee away from the physical location of the work being performed. While you can require that operators spend time in the field locations in order to maintain skills on the actual physical plant (as opposed to the digital world they occupy in central control), we run into the same problem as when we discussed posting operators. Namely, the large periods of time operators would have to spend manually operating signal equipment and away from their intended functions.

Therefore, it is the responsibility of the user design representative to transfer the knowledge base from employees that are on the verge of ending their careers into the central control system. This is a similar effort as we discussed in preserving institutional memory, but design created for today's skill set runs the risk of being too complicated for future generations of operators. Design, therefore must not only consider the lowest common denominator, but the future lowest common denominator. This is achieved by stressing simplicity of all operations, and providing the smart feedback that is gleaned from experienced employee interviews and site-specific operational studies. In essence, the centralized control system should know, and easily express, more about the normal and abnormal operation than any individual future employee.

3.4 Emerging Technologies

The greatest challenge to the Capital Program for a project of this scope is the fact that technology moves at such an accelerated pace, no specification can anticipate the capabilities and needs of a system during the average length construction cycle. Therefore designers must leave the technical aspects of a requirements document vague in order to leave themselves room to insist on the latest technologies.

However, advances such as flexible displays, haptic feedback, and touchscreens are very difficult to acquire unless the specification is written in such a way that the functional requirements can be used as a driver of the technical. Again, this is where the operating department must take the lead. By specifying the ease of use, resemblance to non-work technologies used by operators, and focusing on the speed of operations, we can force the technological hand, regardless what is available at the time of requirements gathering.

3.5 Alarm Fatigue

The lessons learned from the Deepwater Horizon disaster is a cautionary tales about the dangers of alarm fatigue. When every action required is an emergency, none become an emergency.

There is a strong desire on the part of designers to turn every event message into an alarm that must be acknowledged by the operator. This is born out of the lack of serious research into the operations workflow and priorities of the centralized control system operator. Rather than determining the proper arrangement and trigger for emergency alarms, the 'everything and the kitchen sink' approach is utilized. It then is handed over to the operating departments as a procedural issue. Albeit, one that has no hope of being untangled by training or procedure.

Again, the operating department's involvement in the design of any system is paramount. First we must peel away the layers of alarms to get to the core set. Any action that doesn't require an immediate acknowledgement is the first to be removed. Alarm categories as glorified event message lists are the primary driver clutter. Next, any alarm that requires and acknowledgment but requires no immediate action by the operator must be removed. Alarm lists should be treated as emergency events and an emergency event that requires no action is an oxymoron.

Next, events that require an action but the action is a routine task or a task that is normally monitored by the operator should be removed. A train not moving at a cleared signal is so frequent, and can be reported through so many other means; visual confirmation, train operator radio transmission, or visual cue of headway or OTP degradation, that alarming this event is unnecessary and counterproductive.

Any action required for the maintenance of the system, whether on the ATS side, or as a response to indication of a failed field device should be routed to the proper divisional respondent. The operating department cannot be responsible for reacting to server failures just because they are the well-staffed and focused on the system. In actuality, these failure messages do not need to exist within the system itself but can be passed through to text and email alerts to the responsible departments.

A final requirement for the usage and manipulation of alarms is that all events should be indicated visually on the overview and detailed displays. Only when we have whittled the alarm lists down to a small critical set, with full visualization on displays, are these lists even useful to the operation

3.6 Lessons Learned

Based upon our previous experience with large scale indication and control projects, NYCT has developed a specific series of requirements for our future expansion. The overarching theme amongst these lessons learned is that centralized control projects have to be user driven, as opposed to being considered just a variation of a signal design project. This fact, coupled with the operational constraints listed in the preceding sections, leads us to our operational design concept.

First and foremost, incremental change is preferable to large scale modifications. Evolution, not revolution. The big-bang approach places too much pressure on the operating department and the operators themselves to manage organizational change too quickly. It is the goal of RTO to bring indications to the RCC in advance of true train tracking and well in advance of train control. This staggered approach has multiple benefits. It divides the transition of work roles into smaller steps which reduce workload variations on operators. The RCC is responsible for six million riders both the day before and day after a system is completed, and the priority of the project should be to ensure that the differences between the two days are defined by the additional benefits, rather than the new complexities.

Incremental change has a programmatic advantage as well. In the typical, contractor driven centralized control project, time and budgetary constraints force the engineer and users into a series of false choices. An under designed relay logic office system and an under designed user experience compete for valuable resources. Relay logic typically wins the day, as it is the closest to vital functionality and more closely conforms to the written scope of the project. By removing disparate functions from a design project, developers are forced to perfect specific, targeted functions as their sole responsibility. In this manner, the user interface is completed in an environment conducive to focused, user driven development.

This type of piecemeal addition of capabilities also eases the process of managing organizational change. The continuity of operations is preserved and changes that must come under the transition to centralized control are able to develop in the same organic fashion that created the current work environment.

Specific care must be taken to design for the dynamic nature of the workforce and its affect on institutional memory. RTO has committed to cataloging all site specific aspects of its operation while also beginning the process of knowledge transfer to future generations. This is achieved by programming positive feedback into the system. The first time a user logs on with a specific territory right, they will be forced to read a plain language description of the specifics of this new territory and prompted to confirm that they have read and understood the document. Keeping these files available at all times, any user can virtually post at any interlocking or Master Tower in the system.

Just as we identified the most common incidents and their restoration strategies, the responsibility of memorizing recovery strategies should be removed from the end user. All service restoration strategies begin with a blockage in the track way. Although the reasons for the blockage may be infinite, the actual locations are a finite set. Location and projected duration is all the information that is needed to formulate an alternative service strategy. Since this is a specific set of inputs and a limited set of outputs, any train control system should be able to recommend the recovery strategy to the operator rather than wait for the operator to institute a series of strategies. A train stuck at Canal always elicits the response of A line trains via the F line W4th to Jay St and a blockage of a long duration necessitates the thinning out of the service at the terminals. Designing a system that only needs to be told that a blockage exists and be given a projected duration in order for it to automatically begin the reroutes, thin out the service, provide updated customer information, and provide feedback to the operator on the off-line impacts of the incident is just a matter of effective research.

The issue of the man/machine language barrier is solved with plain language triggers for complex actions. Since I today verbally state to a tower operator that I want the A Line to run via the F Line from W4th to Jay St. that should be the sum total of my computer interactions to perform this task. Simple drop down lists at interlockings stating all the available service reroutes, along with train line specific commands ("Turn all C's at World Trade Center"), along with specific actions initiated at origination points ("Go to a 10 minute headway for the next hour") break the linguistic issues that exist in the central control environment.

It can not be stressed enough, the importance of capturing the institutional memory in the system and providing smart feedback to the next generation of operators. Transit is transitioning out of an experienced based operating environment to a knowledge transfer intensive one. Staying ahead of the curve on these stark organizational changes is the principal responsibility of the operating department.

4. ADVANCING EFFICIENCY

We have spoken at length on the issues facing an operating department in trying to minimize impacts and simplify functions. This is a noble task, but at the end of the day, we are only implementing centralized control systems to improve the efficiency of operations and provide more value for the taxpayer dollar. As stewards of NYCT, we assume responsibility of a massive amount of public infrastructure when we begin our careers and hand this system back to the taxpayers when we end our careers. It is the goal to return the system in better condition and operating more efficiently than what we received.

4.1 Incident Handling

The primary goal of the RCC in the current B-Division arrangement is incident handling. Currently the tools provided for this task are the radio system, telephones, an open party line intercom used by multiple departments and Police (6-wire), and field line speakers, channel based intercoms that towers use to communicate. Console Train Dispatchers (CTD) and Desk Superintendents have the use of a static model board that gives basic track configuration and station locations, but provides no indication, and obviously no control. Incidents and delays only come to the attention of the CTD when they are called into the RCC by train crews or line supervisors. This reactive method of command does not allow for quick service adjustment strategies or the ability to use visual cues to determine delays, both during incidents or on the periphery of incidents.

Train location without indication is done exclusively through contacting adjacent towers and deducing the trains that are in the affected areas from what was has passed one point but not yet arrived at the adjoining location. Each of these trains then must be contacted to further determine their exact location, awareness of the incident or delay, and if they are berthed in a station or, in the worst case scenario, between stations with no opportunity to advance into a station. This process takes valuable minutes during the handling of an incident, time that should be spent dealing with the incident train itself.

Any centralized indication and control system chosen for the B-Division will have immediate benefits on this front. As referenced in the section on the history of centralized control, major incidents are the drivers of technological advancement. Although necessity is the mother of invention, public disapproval is its father.

RTO has vast experience with the transition to central monitoring and its affect on incident handling due to its adoption of the technology on the A-Division. Incidents are handled in a quicker and more orderly fashion, with information to the customers, automated and manual, simplified by visual representations of the service available to communications personnel.

The effect on customer safety and faster incident response is the selling point of any centralized control system and is the most focused upon aspect. However, the ancillary benefits are just as important

4.2 Service Delivery

In order to provide efficient, regularly spaced subway service, supervisors and managers must be able to see impacts of their decisions from one end of a line to the other. The current Master Tower arrangement only provides for a short line or corridor level view of the service. The affects of your decisions on sections of the line that are not viewable from master tower machines are unknown, or only indicated through verbal information passed over the line speaker. This arrangement leads to two consequences; service regularity on the periphery of an incident is not directly monitored or controlled by those handling the incident, and delays mount as cascading bottlenecks develop based on decisions made with limited information.

In addition, the manual railroad is beholden to On-Time Performance (OTP) due to the nature of train data collection being manual and at limited time points. While OTP is a valuable tool for commuter railroads and lines where the final destination is also the destination of choice for most commuters, NYCT's ridership patterns negate these benefits. Very few commuters travel to the train's termination point but instead ride small line segments from one point to a destination predominantly in the Central Business District. The concern of these riders is not what time an A train arrives at 207th St., but how long they have to wait for the A train to arrive at their origination or transfer point. To this end, Wait Assessment becomes the predominate metric by which we can judge our service. And only through centralized monitoring with robust train tracking is Wait Assessment generation possible.

User feedback on service regularity through simple concise displays must be the hallmark of a modern centralized control system. Geographically accurate overview displays are space consuming and difficult to design, so the eyeball method of determining even train spacing is insufficient. Instead, system feedback on Wait Assessment at user adjustable time points, trains per hour counters at all stations, and visual user feedback on individual train's conformity to headway adherence are necessary. Alarm lists and event recorders are insufficient in the busy RCC environment. As previously discussed, the entire concept of event notification must be reconsidered and revamped.

The ability to make service delivery adjustments based not on the centralized monitoring itself, but the smart feedback tools built into the system, are the most public-facing aspects of the centralized control effort, along with customer information signage.

4.2 Operational Benefits of Public Predictive Data

In the infancy of the effort to take predictive train arrival information and make it available to web developers, a common concern from the technology field was that RTO does not want train location information available to the public for safety reasons. On the face, the concept doesn't hold water because during rush hour you can guarantee there will be train arriving at Grand Central within the next few minutes if you were trying to do harm. Knowing the actual location of the train is meaningless except in the case on freight railroads where we are not sure if a train is in Montana or Wyoming. But, besides the logical flaw in this thinking they were missing a larger point. Public predictive data has vast operational benefits.

As I walk out of my Manhattan office I have multiple transit options to choose from. I can walk to the N, Q, and R trains at 57th/7th Ave. The A,B,C,D, and 1 lines at 59th/Columbus Circle or the C and E lines at 50th/8th Ave. How I make this decision is based on random chance personal preference. None of this decision is currently based on the operating characteristics of the railroad.
By providing developers of web apps with predictive train arrival times and service alerts in real time we can now steer the Smartphone using part of the population away from problem areas and towards the lines and locations with sufficient capacity. Crowding conditions lessen which provides a service regularity and customer safety benefit. You no longer have to wait to arrive on the platform before finding out at what level the service is running.

Besides the customer facing benefits of predictive train arrival, there are operational and technical benefits as well. In an established, closed source, system such as ATS-A, making modifications to the software to display newly developed metrics is an expensive and lengthy process. The public feed, however, provides an end run around contractor driven change. The same data sets that Smartphone developers use to inform the public can also be the drivers of desktop based performance indicators developed in house. Wait Assessment, String Lines, Train Counters, and other not yet developed performance indicators can be created by the average developer in the web environment.

4.3 Open Data as a Management Tool

Typical central control systems include their own data warehouses and pre-canned reports. The issue arises when the flexile nature of transit operations, organizational change, or simply time requires large changes to the nature of reports and statistics.

An open data warehouse, accessible to everyone in the agency, solves this issue. An analyst level employee can access all data and manipulate it to create new metrics, new reports and new operational feedback. By constantly challenging the operating managers with new metrics and goals, we can avoid an operation that is too On-Time Performance focused or too Delay Minimization focused in its strategies.

By constantly changing the way we measure our performance, and having flexible tools available in any system we design, we can experiment with our strategies and procedures. In the past the results of these alterations might require direct, time consuming observation, or performance statistics that did not reflect the full customer experience. Today, with open data warehouses we have the flexibility to challenge pre-conceived notions about our on the fly effectiveness.

4.4 Crowd Sourcing Operational Experience

The internet community is a rich resource of ideas and concepts that can be farmed for operational benefits. If we, as mentioned earlier, have completely captured all the organizational memory and codified it into our system, what happens to experiences that occur after system completion?

Just like crowd-sourced encyclopedia, Wikipedia, the operating department must give its employees a platform to make observations, report bugs, or share useful shortcuts with the entire department. This crowd-sourced knowledge base can then be converted into the next generation's work towards capturing institutional memory.

5 A VISION FOR THE FUTURE

New York City Transit is lacking in most of the central control capabilities that other agencies are accustomed to. But this provides a great opportunity as well. By skipping generations of technology we are able to introduce central monitoring and control to 67% of our system using the latest industry expertise. Lessons learned, wrong turns, and success stories are available to our designers by just reaching out to sister agencies.

Our goal has surpassed the paperless office and instead has moved on to the experience-less office. An agency where a new employee can sit at a console 5 years hence and have as much knowledge and experience at his fingertips as any operator today. Human error is a major issue for transit agencies and cannot be designed out of employees. However, you can design a centralized control system that guides the human through the decision making process in order to minimize errors.

Based on these facts, and the organizational commitment of NYCT's project team, we are in the process of developing the most intuitive, user friendly, non-training intensive system yet designed.