WILLPOWER, TEAMWORK, & GOOD LUCK

HERE'S HOW SEPTA'S PTC SYSTEM WORKS IN PHILADELPHIA, YEARS BEFORE OTHERS

STORY AND PHOTOS BY BRIAN SOLOMON
Running at 27 mph, a SEPTA engineer is poised to make a brake application as he approaches North Philadelphia on the run toward 30th Street Station. SEPTA has systematically installed PTC signalling on its Philadelphia-area commuter rail system.
the Southeastern Pennsylvania Transportation Authority, was better prepared than most railroads when a Metrolink engineer ran a stop signal in 2008, slamming head-on into a Union Pacific train and killing himself and 24 passengers at Chatsworth, Calif. That led to a federal law requiring railroads to install positive train control, and few in the railroad industry understood what it would take to add the technology. At the time, PTC systems existed, but none had been deployed on U.S. commuter and freight railroads and the tens of thousands of track-miles required.

Nearly 10 years and billions of dollars later, railroad executives realize how hard PTC is to get right.

Fortunately for Philadelphia’s SEPTA, officials had already planned to upgrade its signaling system when the Chatsworth wreck happened.

While the PTC mandate re-focused SEPTA’s choice of technologies, its strong commitment to safety and despite being underfunded, SEPTA found means to secure adequate funding, allowing it to nearly meet the original PTC deadline of Dec. 31, 2015.

By the end of 2017, it had equipped all of its regional rail routes with the Advanced Civil Speed Enforcement System — the form of PTC in use on much of the Northeast Corridor. Today, SEPTA’s operations are largely PTC-compliant, months ahead of the 2018 deadline. SEPTA’s PTC is interoperable with Amtrak and NJ Transit. The last remaining hurdle is coordinating interoperability with CSX Transportation and Norfolk Southern.

**SIGNAL LEGACY**

The development of railroad safety systems has a recurring theme: horrific railroad accidents, followed by groundswells of public opinion demanding improved safety, resulting in widespread introduction of new and advanced safety technologies.

The velocity and large mass of trains has presented problems since the formative days of railroading. Getting a train moving is relatively easy; stopping it safely is a challenge. Unlike road vehicles, trains are fixed on their path and are often moving too quickly to stop for an obstruction in the operator’s line of sight, so other means must be employed to stop trains safely. Signaling is part of a strict rules-based operating culture aimed at aiding locomotive engineers to control speed and stop safely.

Since 2008, development and application of positive train controls represent the most recent evolution of American railroad signaling and rules, intended to overcome the failings of earlier systems and reduce accidents.

Mandated railroad safety technology goes back to the 19th century. Signaling advances continued with railroads including the Pennsylvania Railroad and the Reading Co., whose systems SEPTA inherited.

The agency’s Pennsylvania routes were equipped with automatic block signals and an automatic train control system, kin to Amtrak’s, that had evolved from the Pennsylvania’s steam-era cab signaling system.

Reading had complied with the Interstate Commerce Commission’s signal mandates of the 1920s and installed cab signaling on certain key routes. By the time SEPTA inherited these lines, cab signaling had been removed, leaving lines protected by lineside signaling.

SEPTA’s wake-up call occurred in 2006, when a serious slow-speed, head-on accident on its Warminster Line highlighted the risks of operating without ATC.

In response, SEPTA moved to expand ATC across its network. This was fortuitous, because by the time of the 2008 mandate, SEPTA had a running start to meet Federal deadlines. SEPTA’s systemwide up

**ATC PLUS ACSES EQUALS POSITIVE TRAIN CONTROL.**

grades involved replacing legacy hardware, including phasing out traditional code lines with state-of-the-art aerial fiber optic lines. It also replaced traditional signal equipment with modern hardware and lights. SEPTA prefers triangular pattern color-light signal heads, similar to signals inherited from Reading and Conrail-era installations, but lit with bright LED clusters, which use less electricity, and offer greater redundancy when an individual light burns out. These have largely replaced Pennsylvania-style position light heads on former Pennsylvania lines administered by SEPTA. Amtrak continues to use position light hardware on its lines, including tracks that host SEPTA trains.

Signals were upgraded in conjunction with reconfiguring legacy track arrangements. In some situations SEPTA tracks had been designed to accommodate freight traffic that was gone by 2006.

A key improvement was installation of powered universal crossovers in place of old-style trailing-point hand-thrown crossovers. This was done in combination with installation of bidirectional signaling on lines with two main tracks, which offers greater flexibility and simplifies operations when it is necessary to take a main track out of service.

ATC signal aspects are displayed in the cab, allowing SEPTA to adopt “cab no wayside” operation that eliminated wayside intermediate block signal heads. Wayside signal heads are now only used for absolute signals at control points and interlockings.

**PTC CONDITIONS**

Prior to the 2008 mandate, “positive train control” was only loosely defined. The mandate contained in the 2008 Rail Safety Improvement Act redefined PTC to fulfill specific conditions:
• Prevent train-to-train crashes.
• Enforce speed limits.
• Protect work zones.
• Keep trains from running through a misaligned switch.

PTC conditions were later revised by the Federal Railroad Administration, working through its Rail Safety Advisory Committee, to include protecting grade crossings in the event of automated crossing-gate failures, while making allowances for trains to be operated under restricted speed rules.

PTC systems must enforce stops short of mainline switch-es, plus stops in special circumstances on siding switches where track speed is greater than 20 mph. Systems designed to comply with PTC must be interoperable, meaning that while railroads were free to adopt different technologies, each system needs to be sufficiently compatible to facilitate movements between different systems.

It is one thing to mandate that railroads embrace and install existing and commercially available technology. It’s another to require them to adapt unrefined technology while placing strict deadlines on the application, which is what the initial PTC mandates did. Since there were no fully suitable ready-to-go technologies, railroads needed to work with suppliers to innovate solutions.

SEPTA is an unusual case in that its revenue operations are fully electrified. Although SEPTA has a comparatively large fleet of trains for the size of its network, it has little variation among its rolling stock. Since 2012, it operates two varieties of electric multiple unit, plus eight locomotive-powered push-pull trainsets. Its only other equipment is a few diesel-electric locomotives largely used for maintenance trains.

To maintain schedules over its intensively operated lines, SEPTA’s electric trains are powered by high-voltage overhead A.C. electrification, which allows for rapid acceleration and deceleration using a blend of traditional air-brake and dynamic braking systems.

Its trains often operate on unusually close headways, and its adaptation of PTC needed to take these operating characteristics into consideration. As with most planned PTC installations, SEPTA opted for an overlay system to augment existing signaling and rules.

SEPTA’s operational territory is shared with Amtrak’s electrified high-speed Northeast Corridor trains and Class I freight railroads, which have decidedly different operating and braking characteristics and thus different PTC requirements, which complicated SEPTA’s situation.

At an early stage, SEPTA officials recognized the importance of interoperability and cooperation with Amtrak. SEPTA is an Amtrak tenant on a significant portion of its route mileage, running north 31 miles from Philadelphia’s Zoo interlocking to Trenton, N.J.; south 36 miles from Philadelphia’s Arsenal Interlocking to Newark, Del.; and west 35 miles from Zoo over the historic Pennsylvania Main Line to Thorn interlocking at Thorndale, Pa. As a result of construction of a four-track center city tunnel in the 1980s, linking former Pennsylvania and Reading commuter rail lines, most SEPTA trains operate between the two old networks, originating on one half of the system and terminating on the other. As a result, 47 percent of its weekday trains operate for a portion of their journey over Amtrak owned and controlled lines.

Not only would SEPTA’s implementation of PTC need to be interoperable with Amtrak’s, but Amtrak’s ACSW system itself offered the most affordable and effective way for SEPTA to comply with the PTC mandate.

As SEPTA’s General Manager Jeffrey D. Knueppel, who also chairs an American Public Transportation Association PTC subcommittee says, "ATC plus ACSW equals positive train control." In a perfect world, where time constraints and costs wouldn’t weigh heavily on development, SEPTA may have found a more elegant interpretation of positive train control, but adopting ACSW allowed SEPTA to build upon its existing signaling systems to fulfill the requirements for PTC.

Although SEPTA faced the same deadlines as other carriers, its circumstances put it in a better position to complete implementation than most other operators. Part of this was luck, and part was SEPTA’s aggressive approach to PTC development and installation. And, having the right people makes a difference.

In 2012, as SEPTA was gearing up for PTC, then General Manager Joseph M. Casey gave Knueppel greater authority. Knueppel, then serving as SEPTA’s deputy general manager of construction, mainte-
forced to delay trains, an unpopular move with riders and the local media.

"Do you choose on-time performance or safety?" Kneupel asks. "We had a choice to slow down PTC implementation or accept train delays, and we chose to push PTC over normalcy. It took a while to get our trains back on time."

Adding to SEPTA's challenges was a 50-percent increase in rail ridership since 2000. Then, in 2016, the commuter system faced serious fleet problems.

Defects forced temporary withdrawal and repair of its newest cars, the Hyundai Rotem-built Silverliner Vs, leading SEPTA to borrow equipment from other operators as a stop-gap measure.

One initial downside to PTC is that its enforced braking curves, or braking function, resulted in more conservative operation. The result is that PTC added time to the schedules. However, once all parties become more familiar with PTC, there may be room for improved running times without adding risk.

One of the most difficult installations for SEPTA was on the West Trenton Line, where it was a tenant of CSX Transportation for 6 miles. CSX planned to install the terrestrial radio with global positioning satellite-style Interoperable-Electronic Train Management System made by Wabtec. It is common to Class I railroads, but different than SEPTA's system.

Adapting SEPTA's trains to work on CSX's PTC would be costly and complicated, so instead of a technological solution, the railroads agreed it would be easier to separate freight and passenger operations. SEPTA and CSX cooperated in rapid infrastructure improvements, including adding a passenger track for much of the distance.

This ultimately benefited both railroads' operations while minimizing the technology required for PTC interoperability.
ATC AT WORK

Signal aspects reflect track circuit conditions ahead of the train. In that sense, signal aspects serve two primary functions: 1) they maintain separation between following trains based on block occupancy, and 2) they authorize movements through interlockings while conveying the maximum safe speed of the whole interlocking route.

Automatic train control is designed to provide the engineer with an in-cab signal display that reflects signal aspects displayed by wayside signal hardware.

Where there are no longer wayside intermediate signal heads, the cab signal display provides the necessary aspects formerly supplied by that hardware.

The ATC system transmits aspect information via the rails using high-frequency, low-voltage alternating current carrier signals transmitting pulse codes. This coded data is picked up by ATC induction receivers on the train, where it is amplified and decoded by the in-cab system. Each aspect is assigned a specific code rate defined by the number of electrical pulses per minute. The individual cab aspects may not match, but rather conform to speeds associated with specific wayside signal aspects.

The Pennsylvania system from which the SEPTA’s ATC system evolved uses 180 pulses to display clear line speed; 120 pulses for approach medium, 45 mph; 75 pulses for approach, 30 mph; and no code for restricting — the most restrictive aspect displayed by the conventional ATC system. Historically, the code signal carrier frequency for these aspects was delivered at 100 Hz alternating current, which distinguished it from commercial 25 Hz and 60 Hz electric power and other potential lineside interferences. Amtrak assigns a 250 Hz code signal carrier for the faster aspects of its nine-aspect cab signaling system. Field stations, called interlocking houses, produce and transmit the code signals. Historically, pulse codes were generated by specialized mechanical relays. Today, solid state code generators are used, although certain railroads still prefer relays because of their proven durability.

SEPTA’s ATC offers three-block protection. As a train closes in on a signal displaying stop (for a variety of conditions, including a train stopped ahead, a controlled signal at an interlocking, opened switch, or a system fault such as track circuit defect) the pulse code through the rail drops from 180, to 120, to 75, and then to no code, resulting in the sequential aspect digression from clear to approach medium, approach, and finally, restricting. Each change in the code rate will result in an audible warning to remind the engineer of signal status change.

In the event of an equipment failure, either on the ground or on the train, the carrier code is interrupted. The most restrictive signal instruc-

On the West Trenton route, where SEPTA was a tenant on CSX, the most effective solution for implementing PTC was to reconfigure the infrastructure between West Trenton and Woodbourne, N.J., to separate freight and passenger tracks. Working parallel lines, a SEPTA Silverliner V passes at control point Wood near Woodbourne, adjacent to CSX’s TL interlocking. Patrick Yough

SPEED READING

In its literal translation, “restricted speed” is a misnomer. According to railroad rulebooks this isn’t defined as a specific speed, but a set of conditions, each of which dictates the safe movement of a train at reduced speeds. When operating at restricted speed, the locomotive engineer is required to control train movement by limiting speed of the entire train to 15 mph within an interlocking or 20 mph beyond interlocking limits, while being prepared to stop within one-half the range of vision, and short of other trains or railroad equipment occupying or fouling the track, obstructions, improperly lined switches, derail in the derrailing position, signals displaying stop, and broken rails or misaligned track. A restricting aspect requires a train to obey restricted speed rules. — Brian Solomon
CAB SIGNAL ASPECTS

SEPTA’s aspect display unit, or ADU, displays only four aspects, compared with as many as 20 aspects displayed by wayside hardware. As a result, the cab signal aspect may be more restrictive or convey less detailed information than the wayside signal to which it conforms. The rulebook illustrates a list of wayside (fixed) signal aspects and the conforming cab signal aspect. For example, if the wayside signal displays a medium clear (proceed at medium speed until the entire train clears all interlocking switches, then proceed at normal speed), the conforming cab signal aspect will be approach medium, which when displayed on a wayside signal means “proceed approaching the next signal at medium speed,” but has a 45-mph speed instruction when displayed in the cab. — Brian Solomon

mation — no code — will result in fail-safe operation through the display of a restricting aspect.

While cab signaling systems only provide a warning and rely upon the locomotive engineer to take action, more advanced systems such as the ATC used by SEPTA enforce the speed authorized by the aspect display unit.

The system continuously monitors the pulses in the track, and updates the aspect display unit with the conditions of the block ahead.

An advantage to this system is when the block ahead clears, within about 5 seconds a more favorable aspect should be displayed in the aspect display unit so the engineer will not need to delay acceleration until seeing the next wayside signal.

The track circuit-actuated, block-based nature of automatic train control was designed to aid the locomotive engineer interpreting signal aspects, but not to enforce line speeds, temporary or permanent speed restrictions, or enforce a stop at interlocking signals displaying a Stop aspect. It was up to the engineer to obey the restricting cab aspect and wayside signals, including the instruction to stop short of signals displaying stop.

ABOUT ACES

The Advanced Civil Speed Enforcement System is based on the European Railway Traffic Management System and developed for use on the Northeast Corridor. It was first approved for the Boston-to-New Haven, Conn., segment of the corridor in 1999 when Amtrak was preparing for 150-mph passenger operation on tracks shared with much slower freight trains.

As with the European system, ACES is a microprocessor-controlled cab-signaling system, communicating with trains using a data radio interface and trackside transponders that determine a train’s location with pin-point accuracy. In contrast with traditional ATC, which uses a speed-based protection-warning system, ACES provides distance-based protection, and is known as a “distance-to-go” system.

On Amtrak, ACES with ATC provides for expanded signal aspects on the aspect display unit interface. It provides speed-based warnings and, as required, penalty or emergency brake applications, offering a stop at interlockings and other locations where a stop is desirable. The system was adapted to enforce line speeds, reflecting track geometry and both permanent and temporary speed restrictions, including restrictions (and stops) protecting temporary work zones, and stops at grade crossings with malfunctioning protection equipment, which are among the conditions required of PTC systems. Ansaldo’s adaptation of ASES for SEPTA is designed to be fully interoperable with Amtrak.

SEPTA’s ASES is compatible with Amtrak’s, but uses fewer aspects since SEPTA trains do not travel as fast as Amtrak’s.

Key components of ASES are track-based transponders and lineside data radio transmitters. SEPTA uses Ansaldo transponders called “Static xponders,” located between the rails at strategic locations. These transmit fixed information such as the position of signals and changes to track geometry and provide positive location data for trains. Data radio transmitters allow trains to communicate information to the wayside computers while supplying dynamic information to trains, such as temporary speed restrictions and other changeable conditions that affect train speeds.

This vital information is used by a train’s on-board computer calculating braking curves, or functions, to provide operator warnings, and automated brake applications when warnings go unheeded.

THE HARDWARE

SEPTA’s train dispatchers work from its railroad operations control center in Philadelphia, where they regulate operations by setting switches and signals, and provide instructions, such as temporary speed restrictions, to trains across SEPTA’s network. Dispatchers use computer-aided dispatching consoles modified for PTC operation that communicate coded data via SEPTA’s own fiber optic lines to wayside interlocking houses. These contain

PTC HAD STRETCHED THE INDUSTRY THIN. SEPTA WAS FORTUNATE TO KEEP KEY PEOPLE ON BOARD.
banks of relays for track circuits and switch controls, and are driven by solid-state electronics and computers. To ensure protection from would-be hackers and terrorists, the systems are not connected to the internet.

Signaling equipment is powered by banks of lithium-ion batteries that are recharged using commercial power, and at a few trial locations, on-site solar installations. If solar power proves practical, SEPTA intends to expand its application systemwide.

Consistent with interlocking practice, interlocking signals normally display Stop. In order for a dispatcher to clear signals, interlocking house circuits quickly generate information and communicate checks of vital data necessary to safely set switch points and clear signals (to display more favorable aspects) as permitted by track circuit conditions to prevent conflicting train movements and other dangerous situations.

At locations with two main tracks, a zone system builds a degree of redundancy into the circuits, mitigating against the effects of signal circuit/interlocking computer failures.

Separated, parallel computer systems control each track individually, so in the event of failure, SEPTA retains signal control on one of its main tracks. This allows for operational flexibility on lines with bidirectional signaling. Common cause of failures include lightning strikes, vandalism, and electronic card faults.

If SEPTA’s Railroad Operations Control Center loses control of an interlocking house, a local control panel inside the house allows for a signal maintainer to operate the interlocking on site, much in the manner of a traditional signal tower. To avoid authorizing conflicting moves, specific protocols must be followed for a dispatcher to convey an interlocking house to local control.

The interlocking house communicates data through a fiber-optic connection to an adjacent, but physically separate, radio instrument house. It sends ACSES information to the trains through high-frequency data radio.

The radio instrument house contains a computer rack, featuring a handful of key solid state instruments. On top is an alarm system, followed by the fiber-optic interface, computers, a precision clock synced via GPS connection — as reliable signaling requires the system to maintain accurate time — and a data radio transmitter. Four rechargeable deep-cycle batteries are used for backup power.

The data radio transmits temporary speed restrictions and other information.

PTC AT WORK

ATC and ACSES both supply information to the aspect display unit, including cab signal aspects and two speed indications — the top number indicating the maximum allowable speed, the bottom showing the actual train speed.
BEFORE THE PTC MANDATE...

Mandated railroad safety technology goes back to the 19th century. The United Kingdom’s Parliament passed the 1889 Regulation of Railways Act in response to a horrendous accident on June 12, 1889, that killed 89 people.

The act set an early precedent for application of continuous automatic braking systems and the interlocking between signals and switch points. Both of these are key to safer operations. Safety components of positive train control include linking of continuous automatic braking with lineside signaling equipment.

Although American railroads had invested in automatic block signaling prior to World War I, railroad managers recognized that a fundamental failing of railroad operations was the lack of backup safety systems. People make mistakes, so simply relying on rules compliance without some form of positive enforcement had risks.

U.S. government control of railroads between 1917 and 1920 included investigations of an automatic train control committee, which helped define different systems and potential applications. After railroad control was returned to the private sector in the early 1920s, the Interstate Commerce Commission pushed the development of both automatic train control and cab signal systems, while mandating railroads to install a form of advanced signaling on at least one full passenger division by February 1926.

Results of this mandate included applications of the four-aspect cab signal system developed by Union Switch & Signal and the Pennsylvania Railroad, the forerunner of the modern automatic train control system used by the Southeastern Pennsylvania Transportation Authority and other companies operating former Pennsylvania Railroad trackage.

A defining accident for modern operations was the catastrophic collision on the Chicago, Burlington & Quincy near Naperville, Ill., in April 1946. Forty-seven people died when the Advance Flyer made an emergency stop on the main line and was struck from behind by the Exposition Flyer on the famous triple-track raceway.

Following an ICC investigation, new industry-wide speed restrictions went into effect in 1947, limiting passenger speeds to 80 mph unless protected by an approved form of advanced signaling: automatic train stop, automatic train control, or cab signals. Most railroads responded by lowering maximum speed limits to 79 mph, and there was relatively little investment in advanced signaling systems.

— Brian Solomon

speed — while giving the engineer visual and audible warnings, indicating changes to maximum allowable speed, the condition of the system, and warnings if expected inputs are absent.

Imagine a situation where a train has three clear blocks before reaching a signal displaying stop; the ATC displays a clear aspect with a green light, and allowing operation of the maximum track speed that may be as fast as 80 mph.

Owing to an approaching restrictive curve, track speed is 60 mph, and that is the speed displayed in the top speed window.

The train continues, and the track speed drops from 80 to 60 mph because of the curve. This is communicated to the train via the transponders, enabling the on-board computer to recalculate braking functions. The engineer receives a status-change warning using a rapid series of tones. He must acknowledge the change within 3- to 6-second intervals by pressing a large yellow button below the air-pressure gauges, while initiating an air-brake application called suppression.

Making a 20-pound reduction to the air-brake train line is a suppression because it “suppresses” the computer signal that would initiate a penalty brake application.

This slows the train to the required 60 mph or less. If the engineer doesn’t acknowledge the warning in time, the train’s computer makes an emergency brake application, and if suppression isn’t made in time, the computer makes a penalty air-brake application.

There’s a second status change as the cab signal changes to approach medium, yellow over green, reflecting the track circuit conditions of the next block. Although line speed is still 60 mph, the approach medium requires speed reduction to 45 mph, and that is the maximum speed displayed in the top window. The system goes through the same warning sequence. However, in this instance, a 20-pound reduction slows the train more than is required, so the engineer
uses the throttle to bring the
train back up to 45 mph.

At the next block, the cab
signal downgrades to ap-
proach, or yellow, with a maxi-
mum speed of 30 mph. At the
end of this block, as the train
approaches the stop displayed
by interlocking signals, the cab
signal displays restricting or
red, which comes with a maxi-
mum speed of 20 mph.

However, as the train nears
the signals the on-board com-
puter drops the maximum
speed to enforce the stop, re-
ducing to 3 mph, then 2 mph,
then 1 mph and finally to zero.
This prevents the engineer
from running past the signal.
And without going through
special procedures to override
the system, the train will
remain stopped until a more
favorable aspect is displayed.

PTC doesn't run the train,
the engineer does. PTC inno-
vations are designed to supple-
ment the engineer's road
knowledge and running expe-
rience while enforcing speeds
when the engineer fails to keep
the train under control. How-
ever, PTC's braking functions
are conservative and provide a
greater degree of caution, so
with PTC enforcement an
engineer will often need to
brake sooner and with more
force than before PTC.

RESTRICTIONS

Prior to PTC, temporary
speed restrictions, including
those for work zones, were
protected by amendments to
the timetable issued to operat-
ing crews via paper authority,
as governed by the rulebook
such as daily bulletin orders or
"form D" instructions.

These may be provided to
crews verbally from the train
dispatcher using standardized
language via the train radio,
and then repeated back verba-
tim and confirmed. Under
PTC, additional safety is pro-
vided by the dispatcher, who
keys into the dispatching con-
sole temporary speed restric-
tion information. This is con-
voyed to trains through the
radio instrument house that
supplies the train's computer
with information to enforce
the temporary speed restric-
tions in a manner similar to
the protection of permanent
restrictions. This includes the
ability to ensure a stop prior to
entering work zones.

PTC necessarily includes
strict protocols and overrides
to enable trains to safely pass
signals displaying stop, enter
work zones, and other situa-
tions where it is desirable to
override system enforcement.
Without this ability, the rail-
road would become immobi-
lized in the event of signaling
failures. The rules specify that
train crews obtain permission
from their train dispatcher
before enabling overrides.

A WRAP

SEPTA's successful PTC im-
plementation is significant,
because it was among the few
large PTC users that nearly
achieved the original 2015
completion mandate. By the
end of 2017 it had equipped all
of its regional rail routes with
the hardware, software, and
training necessary to call the
network PTC compliant, ful-
filling most conditions of the
mandate across its system, a
year ahead of schedule.
How to make PTC work

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