Development of an Hump Process Control System

By

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Abstract

BNSF has successfully developed and deployed an internally designed HPCS (Hump Process Control System). In 2010, BNSF recognized the legacy control systems at all nine hump yards were reaching, or had reached, a critical point of sustainability. Historically these uniquely coded systems were purchased from specialized contractors and installed with the expectation of a fixed lifespan due to hardware obsolescence. Additionally, existing systems were isolated from internal networks, which made network wide hump data analysis (for trends, predictive analytics) and remote monitoring ineffective. Recognizing this cycle of installation and obsolescence, a decision was made to replace all legacy control systems with an internally developed next generation system. The goals of the next generation system included:

• Sustainable/modular design
• Standardized logic with configuration capability
• Integration into BNSF systems
• Sustainable internal knowledge base
• Predictive maintenance
• Centralized system management with 24/7 remote monitoring and tech support

This paper will discuss some of the challenges encountered during the project and how these were addressed.
Biographies

Bio Daniel Pittman:

Dan Pittman is the Director Signals for Terminal Process Control at BNSF Railway in Kansas City, Kansas. A position he has held since 2013. Dan joined BNSF in 2005 after spending 10 years with Stahl Specialty Company, a permanent mold aluminum foundry, where he headed up the Engineering and Tooling departments. Dan holds a degree in Mechanical and Aerospace Engineering from the University of Missouri. He is currently a member of AREMA Committee 14.

Bio Michael Lee:

Michael Lee is the Engineer Signals for Terminal Process Control at BNSF Railway in Kansas City, Kansas. A position he has held since 2013. Michael joined BNSF in 2006 after spending several years with UPS, where he worked in a facility engineer role. Michael holds two degrees in Electrical Engineering and Physics from Purdue University. He is currently a member of AREMA Committee 38.

Bio Mark Vande Brake:

Mark Vande Brake is the Assistant Director Signals for Terminal Process Control at BNSF Railway in Kansas City, Kansas. A position he has held since 2014. Mark joined BNSF in 2006 after spending 10 years in the power and controls industry. His past experience includes working in the oil industry, substation automation and consulting engineering. Mark holds two degrees in Manufacturing Engineering and Industrial Engineering from Kansas State University.

Bio Joe Saylor:

Joe Saylor is a Director in Technology Services for the Terminal Process Control system at BNSF Railway in Fort Worth Texas. A position he has held since 2014. Joe joined BNSF in 1998 and has held various positions at BNSF. Currently Joe has responsibility for BNSF’s core Transportation System. Prior to BNSF, Joe spent several years at EDS supporting the Texas State Medicare and Medicaid systems. Joe holds a Bachelor of Science from the University of Texas at Arlington.
Introduction

During development of the HPCS challenges were encountered. This paper will specifically discuss four of these challenges.

First was to ensure seamless integration of the two independent groups would lead to a system that was user friendly and met the requirements of all the stake holder departments. This would be a challenge as the TS (Technology Services) and Signal teams were not co-located and had different business backgrounds, business cultures, and processes.

Secondly, the time line of 30 months to develop and deploy a new reliable software from a blank canvas would mean an aggressive schedule.

Thirdly, members of both teams had limited exposure to hump process control systems. Long term viability would require a broad knowledgebase among the combined team.

Finally, existing infrastructure in most cases had not been upgraded since the legacy systems were installed and in some cases spanned several upgrades. Cabling followed a centralized control philosophy and had been in service for some time. There was limited connection to the legacy systems for data mining. Power systems were centralized to large battery room which allowed for a single point failure. Large amounts of obsolete hardware and limited off the shelf solutions. Lightning/surge suppression had limited effectiveness. Off the shelf computers had limited lifespans and quickly became obsolete or unreliable. Track conditions in most cases were poor at best.

Approach

Integrating the teams.

The Technology Services and Signal teams recognized early on the lack of a co-located team could lead to mismatched priorities. It was determined, in order to keep the team synchronized, regular planning and coordination meetings were required. The combined team set up and participated in scheduled weekly calls, biweekly face to face meetings, and impromptu conference calls to update activities. Decision documents were created to track key decisions and communicate direction to the broader group.

A contracted PMO was hired with a background in software development for real time control systems to manage the combined schedule and documentation. This assisted the teams in synchronizing work on objectives. The tracking from an independent outside resource helped with schedule accountability.
In order to solve larger challenges and to ensure the project was held to the original goals, a steering committee was established with the Senior Leadership team. The committee met regularly to discuss; schedule status; milestones achieved; and support needs.
As the team was mostly unfamiliar with development of a new HPCS, a seasoned veteran of HPCS development was needed. There was a limited number of people in the industry with this background. BNSF was fortunate to get the developer of the ProYard ® HPCS to come out of retirement and shepherd the team through the process as our SME (subject matter expert). It was determined he would be co-located with the developers in Fort Worth. This individual’s background allowed them to provide input on functional requirements, software development, as well as Signal hardware requirements to ensure the systems worked in concert with each other.

Finally, it was important the system met the expected goal of a standardization. The team worked with all the stakeholder departments to create focus groups for the transportation, mechanical, and engineering teams. These teams met regularly to communicate desired features and to review modules of the system. After several meetings it was clear on many issues there was not a consensus among users and in some cases requested features would require significant effort for perceived minimal business need. In order to resolve these conflicts, a senior focus group was established with department heads to ensure feature requests were reasonable and to settle disagreements. Additionally, desired features not covered in the original release were ordered in priority around effort and business need. These would be released in future versions.
**Software development**

A traditional approach would have the functional specifications serving as the primary driver for the process, followed by the technical specifications, and finally the software code. With the limited timeline and lack of internal knowledgebase on the operational specifics, it was determined the SME (Subject Matter Expert) would directly write the required 54 technical specifications. The code would then be developed from these. The functional specifications would be reverse engineered from the technical specifications.

To develop the Next Gen HPCS, the team leveraged an Agile development methodology. The team felt this methodology provided the best path to success because of its collaborative and iterative approach. Unlike traditional forms of software development which involve a lengthy requirements gathering process followed by an even longer software development cycle, the Agile method relies heavily on constant communication and collaboration yet results in shorter delivery cycles which add business value at each stage. For instance, the Product Owner/SME was co-located with the software engineers and this coupled with the daily Scrum meetings and other agile ceremonies with the Signal team allowed the entire team to quickly respond to changes in direction with the product. The iterative nature of delivery also allowed the team the opportunity to rapidly review each completed module with the Transportation department and the Signal focus group to receive early feedback.

The new HPCS is built on Open Source Software using open standards.

**Why Open Source Software, Open Standards and Interfaces?**

- **Lower software Total Cost of Ownership**

  In most cases, Open Source software platforms are free to users but if there are major issues with the platform, the user is on their own to resolve. Fortunately, there is also a path where entities can leverage supported versions of the same open source software by paying subscription fees to the software companies that provide the open platforms. These subscription fees are significantly less expensive than the traditional software licensing model costs for proprietary software. BNSF is realizing a lower Total Cost of Ownership for the software because it is not paying these traditional software licensing fees.

- **Enhanced Creativity and Innovation**

  The Open Source platform allowed the team more flexibility and better innovation while building the product. It enabled creative feature development and problem solving that would not have been possible if a traditional proprietary software platform was used. For example, the team hit a roadblock with one of the database features that was natively available in the open source platform and the team was able to create a custom solution to get past the issue. The team was able to do this because of their complete access to the source code of the platform.

- **Sustainability**

  The Open Source platform is a more sustainable solution for the team and better fits the strategic direction of bringing HPCS expertise in house. The BNSF Technology Services team has built a core team of software developers and engineers that have become experts on how HCPS software operates. Because the team has complete access to the platform and its features, the team has created robust documentation which allows the team to keep their knowledge current.
Product Configuration and System Integration

The modern HPCS base system is standardized but is almost completely configurable by feature. The custom configurations allow the team flexibility to customize the feature for each of the nine locations and by user. This strategic capability will reduce the software maintenance cost over time.

BNSF is currently on the journey to modernize its core rail operating systems and HPCS’ modern-open standards architecture will enable ease of integration as these new systems come online.

Knowledgebase

In order to meet the goal of a sustainable system, development of the team knowledgebase would be critical. The team recognized early that turnover of key personnel would be inevitable. It was determined good documentation would help when transitioning new members to the team. As the SME developed the technical specifications for each module the Signal team would reverse engineer it to develop the function specification. This not only served as the repository for the system designed but forced involvement and understanding of module operation. This helped tremendously when developing test plans. Decision documents were once again used to ensure future changes would have the benefit of understanding why a specific direction was chosen. This process allowed the team to review the pros and cons of various options.

Functional Specifications

Knowledgebase transfer was not only important to the development and engineering teams but also with operators and field support. The team determined the best way to handle this was well documented
technician and operator manuals. The technician’s manual was created to cover all the system hardware and training classes were held where all local technicians and maintainers were brought up to speed. The manuals also include links to the functional specifications which allow a deeper review by technicians in the field if desired. On the transportation side, an operator’s manual was developed to cover all the system functions and training classes were held to cover all operators holding qualification to work in the hump. Historically systems have used generic logins for system control. With an integrated system it was decided for security purposes to tie the login to the BNSF intranet access. This ensures once an individual is removed from the network access to the control system is also removed and allows for accountability as all commands are logged by the user. Mechanical and Transportation employee access to the system is controlled by local officers who are allowed to set roles and responsibilities for individual employees. A user administration guide was developed to assist in the process. Signal employee access is controlled by Signal Engineering.

User Administration Documents

In order to ensure support would be available when needed, the team determined a 24 hour signal call desk to provide immediate troubleshooting assistance was needed. The team recognized it was important to have staff with the right background and skill set to provide remote assistance. The Signal team worked closely with the BRS (Brotherhood of Railway Signalman) to create a new ETSS (Electronic Technician Support Specialist) class scheduled position. Long term these positions will also provide training to new local signal personnel when turnover occurs. From the primary command center in Kansas City all yards can be simultaneously monitored. The ETSSs review standard reports for trends such as equipment failure, misroutes, hazmat handling, and coupling speed reports, to help address issues before a significant failure. Since all yards are integrated we can also look for bad performing cars that have exhibited issues at multiple yards and notify our mechanical team of issues.

Additionally, as the desk is fully integrated into the corporate intranet, the ETSS can also use the camera system to visually compare incidents to the system logs. Yards are also issued a small portable camera that can be set up in a bungalow during troubleshooting to provide a virtual presence.
The team understood consistency of issue handling would be critical to the ability to review past incidents for application to recent failures and to spot trends. It was decided business processes would be needed to clearly outline how calls, issue handoff between shifts, communication, and escalation would be handled. These processes included flow charts, a web tracking tool, and a database for tracking frequency and types of calls.
**Web Based Issue Tracking Tool**

During the two year development and five year deployment the existing systems would continue to be at risk. To ensure sustainability of the existing systems, maintenance contracts were established with existing hump vendors to provide support in case of outages. Additionally, an obsolescence engineer position was established to develop unique hardware replacement solutions where needed. For more details on this, please refer to “A novel approach to obsolescence engineering for long term classification yard infrastructure.” JP Langan, Consulting Systems Engineer, BNSF Railway, from the 2015 AREMA conference.

In previous installations BNSF had used classical survey techniques to identify and catalog all the hardware throughout the hump yard. When the project was started business conditions were seeing traffic at near record levels and availability for surveying would be at a cost to production. The team looked at multiple options and ultimately decided LiDAR would provide the best solution. However, at the start of the project no hyrail vehicles could negotiate the active retarders. The team worked with Bartlett and West on a LiDAR solution that could work within a hump at the required accuracies. A unit was mounted on the front of the hump set in a specifically designed cradle and then ran into the yard between cuts. This not only reduced the data gathering time from several weeks with a traditional stick survey to a few days (in some cases a single shift), but eliminated any need for protection of forces on the ground.
Once the data was gathered the team worked on site at the consultant’s location to develop standards for how the data would be extracted and delivered.

Locomotive with LiDAR scanner rack and GIS data

In order to reduce the probability of a single point failure, the decision was made to move from a historic centralized system concept to a modularized approach. This meant I/O gathering devices would be needed in the field with a robust network to communicate back to a primary processor. Usually this has been done with computer I/O servers. After reviewing the needs of the system and the goals of a sustainable system, it was decided to use a Siemens series 7 PLC for I/O gathering and direct process control of switches and retarders. The Siemens product was chosen for its hardened nature, speed, and long term viability. In some cases serial inputs were converted directly to Ethernet and routed through the control network to the primary processor.
With the decision to move to a modular approach, this meant the existing cabling would need to be replaced. An effort was launched at each yard to replace cable along with installing the PLC network. Once complete a cutover rack was used to shadow between the two systems. The use of the cutover PLC simplified the cutover process and allowed for individualized component and module cutover. The picture below shows how the network and distribution was laid out.

Working with the TS group and the SME requirements were set up for the processing speed of the control network. It was decided a dedicated control network would be needed to ensure intranet traffic slowdowns would not affect control. The system was designed with a fiber ring for each house. This allowed the benefits of a ringed fiber loop and an expedited recovery of the network in case of a fiber cut. With fiber to each house the decision was made to include a connection to the BNSF intranet. This would allow for VOIP and a working network connection for trouble shooting. Additionally, the system is connected to the intranet via redundant connections when possible. The intent is to avoid a single network switch or fiber cut leading to a connection failure.
In order to maintain a sustainable computer platform, it was decided the computers would be replaced on a standard 5 year refresh cycle. Even with the refresh cycle, the team recognized the need to provide a greater level of monitoring and support. It was decided to use a server class computer. This enabled the team to leverage Dell® for remote support and servicing but also these would be monitored remotely by our 24 hr SST (Server Support Team) desk for faults. Any faults can be immediately addressed by local personnel or they can dispatch second level support with a guaranteed maximum response time of 4 hours.

Historically large battery rooms were employed to provide temporary backup power in case of an outage. With distribution of control, it was decided to distribute battery power in order to prevent single point failure of DC power. 480V AC was distributed to each house and a MVB (Multi Voltage Battery) plant was developed in conjunction with an Eltek® to provide all needed AC and DC power supplies (12VDC, 24VDC, 110VAC, 130VDC, 265VDC). With generator backup, it was decided battery capacity was only needed to provide a graceful shut down of the yard while the generator was brought on line. This allowed for the relatively compact (2ft x 2ft x 6ft) rack mounted solution shown below.
When selecting hardware the team was unable to find an off the shelf solution for the DTC (distance to couple) system. This system is very similar to a crossing predictor in that it senses a phase shift to determine how full the track is and provide an estimated coupling distance to the prediction routine. After evaluating several options the team decided to work closely with a vendor to develop a new solution that provided an improved speed prediction with self-tuning capabilities. Additionally, to ensure long term viability an internal solution was developed alongside this to provide the same functionality using a classical approach. The communication package for both devices is identical to allow for convenient switching between devices without impact to programing.

Lightning and surge protection is of great concern in yards due to the density of equipment significant amount of solid state devices. The team wanted to ensure all efforts were taken to provide a robust surge protection strategy. A study was undertaken to evaluate the various devices available on the market and their effectiveness. Testing was performed at a UL certified lab to verify published claims. Ultimately for DC voltages a three tiered approach was designed providing a high pass voltage surge suppressor, a medium pass voltage suppressor, and an optical isolation device for low voltage surges. AC surge suppression was also provided. These devices are monitored by the system to ensure failures are addressed immediately.
Surge Suppressor Testing

It was important to ensure the new system was placed into service on a good platform. A group was formed with our TR&D (Technical Research and Development) department to determine what track conditions most affected the rollability of cars. After multiple modeling scenarios and comparison with real world data, a final report was completed detailing not only the effects of various track conditions but also recommended changes to the prediction routine to better define energy loss through specific segments. Funding was allocated for each yard that included rail replacement/grinding, turnouts, and ties. The majority of work was focused between the group retarder and the tangent point of the class track where the majority of energy loss occurs.

Track work in Tulsa, OK
Conclusion

The first system went live December 1, 2015 in Memphis Tennessee. The goal of this initial “go live” was to have a system functionally equivalent to the legacy system in terms of routing, control, and protection. Fine tuning and additional functionality would be added as the implementations progressed. Second yard is scheduled to go live July 14, 2016 this includes many of the additional requested features from the focus groups. As of publication of this paper 100,000+ cars have been humped on the new system. Rollout will continue to the remaining yards with anticipated completion in 2018.

First car in Revenue Service 12/1/2015, 6:15AM, Memphis, TN
Map of BNSF nine hump yards
Development of a Hump Process Control System

Dan Pittman
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Background
BNSF’s nine hump yards

Introduction
Next Generation System Goals
• Sustainable/modular design
• Full integration into BNSF systems
• Sustainable internal knowledge base
• Smart predictive maintenance
• Centralized system management with 24/7 remote monitoring and tech support

Introduction
So why an internally developed system?
• Strategic
  • Long term viability
• Knowledgebase
• Grow as needed
• Obsolescence management

Introduction
Challenges
• Integrating the TS and Signal teams
• Software development
• Knowledgebase
• Infrastructure

Integrating Teams
• Planning and coordination meetings
• Decision documents
• Contracted PMO
• Steering committee
• SME
Software Development

• AGILE delivery
• Open Source Software, standards, interfaces
  • Lower cost of ownership
  • Enhanced creativity and innovation
  • Sustainability
  • Product Configuration
• Strategic Initiatives
• and System Integration

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Knowledgebase

• Development of team knowledgebase
• Functional Specification Documentation
• Developed from Technical Specifications

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Knowledgebase

Operator/Technician manuals and QR cards

Training

User Administration

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Knowledgebase

24/7 Technician desk

• Monitoring
  • ET support specialist
  • Equipment failure
  • Maintenance planning support
  • System level car performance analytics

• Trouble shooting assistance
• Enhancement request and issue tracking

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Infrastructure

Managing Obsolescence

Obsolescence Engineer
Spare parts

Survey - LiDAR

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Infrastructure

• Modular Approach
  • PLC I/O and control
  • Fiber loop BNSF and Control network
  • Redundancy
  • Power

• Surge Suppression
• Tiered approach

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Infrastructure
- Trackwork
- BNSF Technical Research and Development department study
  - Focus areas
    - Curves after final retardation point
    - Turnouts
    - Rail profile
    - Alignment
    - Class of track

Conclusion
- Targeted installation date 12/31/2015
- System went live 12/01/2015, 6:15AM
  - Lessons learned
    - Testing plans

Conclusion
- Five yards constructed and in shadow mode
- Second yard scheduled to go live July 2016
- Schedule
  - All yards constructed and in shadow by mid 2017
  - All yards in revenue service by end of 2018

Questions?