UTILIZING ACCELEROMETERS FOR AVALANCHE DEBRIS DETECTION ON THE BNSF RAIL GRADE

Richard W. Steiner[1*], Mitch Beard[2], Adam Clark[1], and Ross Sterling[2]

[1] *David Hamre & Associates LLC, Anchorage, AK. USA*
[2] *BNSF Railway, Fort Worth, TX. USA*

ABSTRACT: Since 2005 BNSF Railway (BNSF) has operated an avalanche safety program (Program) in John F. Stevens Canyon (JFS) of northwestern Montana, USA. The Program is comprised of BNSF personnel and avalanche safety specialists employed by David Hamre & Associates LLC. A key attribute utilized for avalanche forecasting are "*slide fences*." Slide fences are binary detection hardware comprised of horizontal wiring strung between posts installed on the uphill side of the rail grade in geohazard areas. If one or more of the slide fence wires is broken, an indication alerts BNSF crews that hazardous debris may be present at that location. In February 2017 a widespread avalanche cycle occurred in JFS Canyon. During this cycle, a natural, Destructive Size 3, dry slab avalanche buried the rail at a location now called *Path 1183*. When this avalanche occurred, Path 1183 was not included in the Program forecast area nor did it have slide fencing installed. BNSF Signal Department (Signal), a department committed to development and maintenance of rail detection systems, including slide fence, was tasked with creating and installing avalanche detection at this site. Instead of wired slide fence, Signal decided to use an array of *L.B. Foster* accelerometer tilt sensors with a Human Machine Interface (HMI). This is the first time BNSF has utilized accelerometers instead of wired slide fence for avalanche detection. Advantages of this new system include site-specific wireless detection, simplified maintenance, reduced false alarms, and an HMI outside of the path.

KEYWORDS: BNSF Railway, Accelerometer, Slide Fence, Avalanche Detection

1. BACKGROUND & SETTING

The Montana Division BNSF Railway Avalanche Safety Program (Program), began in January 2005 and was implemented due to seasonal avalanche activity that has affected rail operations dating back to the late 1800s. The Program is a cooperative effort comprised of BNSF management and avalanche safety specialists (forecasters) employed by David Hamre & Associates LLC.

The Program is based out of Essex, Montana, USA which is in John F. Stevens Canyon (Canyon) near the Continental Divide of northwestern Montana.

Program operations focus on managing avalanche risk for approximately 11 lineal kilometers of rail grade that traverses avalanche-prone terrain in the Canyon. This area is referred to as the Program Area (Area). BNSF infrastructure in the Area consists of single and double main rail, supporting equipment for rail operations, and 10 snowsheds. Snowsheds provide protection from avalanche debris in the larger paths and have a combined lineal length is 1.73 kilometers. Rail grade elevations range from 1045m on the west end of the Area to 1400m on the east end.

On average, between 28 to 35 trains travel through the Area daily which includes two passenger trains. BNSF maintenance employees and vehicles also travel through this section regularly, sometimes multiple times per day. On occasion, workers are performing their duties outside their vehicles within the Area.

The avalanche-prone terrain threatening the BNSF rail grade consists of 18 individual avalanche paths with numerous starting zones. These paths can produce avalanches up to Destructive Size 3+.

Avalanche starting zone elevations vary between 2218m and 1600m. Numerous avalanche-prone roadcuts are also prevalent in the area and capable of depositing substantial amounts of avalanche debris on the rail grade.

Starting zone aspects in the Area are predominantly easterly and southeasterly with one northerly aspect. Return intervals for destructive size 2 (D2) or greater average two (2) to three (3) years, Clark et al. (2022).

Avalanche terrain threatening the rail grade is located on federal lands managed by the United States National Park Service (NPS) in Glacier

* *Corresponding author address:*
Richard W Steiner, Jr., David Hamre & Assoc.,
PO Box 4203 Whitefish, MT. 59937
tel: +1 406-212-0588
email: ted.steiner@protonmail.com

National Park and, the United States Forest Service on the Flathead National Forest.

1.2 Program Complexities

A unique attribute of the Program is that the NPS prohibits BNSF any preemptive avalanche hazard mitigation in Glacier National Park. Explosives and/ or other means of avalanche mitigation are only permitted after NPS officials have determined extenuating emergency conditions (avalanche conditions) exist and a special use permit is issued. This parameter was set in place in 2008 following a NPS Environmental Impact Statement Record of Decision.

1.3 Program Forecasting

Given the NPS restrictions on active hazard mitigation, the Program must rely on forecasting and BNSF operational restrictions to reduce risk (avalanche risk). Forecasting is entirely based on observations related to natural avalanche activity, snowpack structure, and weather. Other than forecasters manually testing snowpack stability in profile stability tests or on test slopes, there is no opportunity to test snowpack stability in a controlled setting.

When substantial storm cycles and/or persistent snowpack instability impact the Area, uncertainty associated with avalanche potential, timing, and magnitude increases and recommended restrictions for BNSF elements at risk are implemented by Program forecasters.

2. BNSF WIRED DETECTION FENCING

A key piece of BNSF infrastructure that Program specialists monitor for avalanche debris at the rail grade are slide fences. BNSF has historically installed and maintained this wired fencing that is positioned on the uphill side of the rail grade, but below identified natural hazard areas associated with rockfall, mudslide, and/or avalanches.

Fencing is installed and maintained by the BNSF Signal Department (Signal) along with other signal-related infrastructure on the rail grade to ensure safety for trains, vehicles, workers, and passengers.

2.1 Wired Fencing Function

Fencing is binary in design and consists of mutiple voltage-charged strands of parrallel wire strung between posts (Photo 1). If one or more wires in a partiular fence are broken, an indication is provided to BNSF dispatchers and crews that a fence has been compromised within a particular section of rail grade (known as a block) and hazardous debris may be present and/or have damaged the rail grade. A block varies in lineal distance along the rail grade and may incorporate numerous individual fences. When a slide fence detection occurs in a particular block, it eliminates the ability for any other indications to be reported in that block.

Also, when a detection is indicated, speed restrictions are imposed on train traffic to 32 km/hr (20 miles/hour) and will remain in place until the broken wire(s) of all fences within a block are found and repaired.

Photo 1: Slide Fencing

2.2 Wired Fencing Winter Maintenance

During winter months fence wiring needs to be manually shoveled out by handcrews for repair or to prevent wire breakage and false indications by snow creep. Also, as winter snow depths increase, the instances of wildlife breaking through fencing also increases. False indictions caused by wildlife are not uncommon and require onsite visits by field-based Signal crews to assess and conduct needed repairs.

Photo 2: Clearing avalanche debris on a slide fence.

In all instances regarding fence maintainance and repair, crews are working diectly beneath identified natural hazard areas (Photo 2).

3. THE 2017 AVALANCHE CYCLE

Beginning in early February 2017 a significant winter storm impacted the Program Area. In roughly 36 hours over 130 centimeters of new snowfall accumulated at rail grade elevations and direct- action avalanche activity was widespread. BNSF operations ceased due to avalanche activity, amount of new snowfall, and inclement weather

At approximately 2230 hours on February 7th, 2017, a natural, Destructive Size 3 avalanche released in a path that, at the time, was outside the Area and where no slide fencing existed.

This avalanche terminated on the low side of the rail grade and deposited 1.2m to 1.8m of debris on rail grade (Photo 3), Steiner and Clark (2017).

Photo 3: Path 1183 avalanche debris terminus on the rail grade.

Thankfully, this avalanche occurred when the rail grade was closed to train traffic and maintenance crews were not in the area. The February 2017 cycle spanned five days between the 5th and 10th. During that time, a substantial amount of fencing was destroyed by avalanches. No other Railway elements were damaged, and no human injuries occurred.

4. ACCELEROMETERS FOR AVALANCHE DETECTION

Following this impressive avalanche cycle, the D3-producing path was included in the Program Area and named, *Path 1183* (1183). Forecasting at 1183 began immediately and plans for establishing avalanche detection at the site was promptly undertaken by BNSF.

To do this, BNSF began exploring new technology for avalanche detection at 1183 with a goal to develop a non-wired detection system that required minimal maintenance, utilized the BNSF fiber communication system, and was capable of rapid installation.

This project was developed in three phases:

Phase 1	Proof of Concept
Phase 2	Hardware & Software Development
Phase 3	System Integration

4.1 Phase 1, Prototype Testing

During the conception, (Phase 1) Signal evaluated LiDAR, Radar, Infrared, and accelerometer sensor equipment for detection.

Signal chose the accelerometer (sensor) option and teamed up with an international company, LB Foster to explore the use of these for detection in 1183.

Historically, LB Foster had been involved with transportation based natural hazard detection utilizing LiDAR, but in the case of 1183, BNSF collaborated with them to design sensor prototypes. Ultimately, LB Foster developed, and trademarked all components of the 1183 wireless detection system which is now referred to as *Avalanche Total Track Monitoring™*, LB Foster (2019).

BNSF's motivation for pursuing the LB Foster system was related to:

- Safety while conducting field maintenance.
- Simplicity in design.
- Sensor specific detection and alerts.
- Comparably inexpensive.

To ensure quality control in Phase 1, Signal employed a field-testing regime where collected field data would substantiate whether these sensors had the ability to detect and alert as needed for the presence of avalanche debris on, or near the rail grade.

Signal worked with Program forecasters in the late winter and early spring of 2018 to install a test-piece system in another avalanche path named *Path 1163* (1163).

Photo 4: Path 1163 upper elevation test-site sensor.

For this test, Signal had Program forecasters temporarily install five (5) sensors in the 1163 avalanche path with the upper two sensors positioned approximately 300m lineal distance above the rail grade and the lower three sensors 150m lineal distance above the grade.

The lower sensors were mounted on PVC piping secured to trees and the upper elevation sensors were mounted on PVC pipes driven into the existing snowpack (Photo 4).

The intent was to test sensor sensitivity and the operation of system components in the field. If the sensors were hit by an avalanche, the goal was to observe if system components would function properly.

The 1163 system consisted of the sensors, a Relay, and a Gateway. Theoretically, if impacted by an avalanche, sensor(s) powered by D-cell batteries, would send a radio signal to the DC powered Relay on the rail grade. The Relay would then transmit the received data to a DC powered datalogger unit called a Gateway. Once these event(s) were recorded by the datalogger, data would then be available for Signal field technicians (Maintainers) to electronically download from the Gateway.

During the 1163 testing period, numerous false-positive recordings occurred as wind would move the trees and/or the upper elevation PVC pipes would melt out and either tip or fall over. However, in early May of 2018, an upper elevation sensor was struck by a relatively small natural avalanche and the event was recorded by the system datalogger. The system preformed as designed, Steiner and Clark (2018).

Further, to help fortify confidence in system function during the testing period, Program forecasters would manually tilt the 1163 sensors on a random basis, record date and time, and then communicate with Maintainers to verify data had been recorded at the Gateway. The 1163 system testing provided Signal with sufficient data and promising results to proceeded to Phase 2.

4.1 Phase 2, System Development

Phase 2 began as Signal refined the final system's hardware and software while also installing a temporary system above the rail grade, only now in 1183. The temporary configuration was like that in 1163, but in this case, the Relay was eliminated, and the Gateway was tied into the BNSF detection network. The sensors spanned the entire runout zone in 1183 running parallel to the rail grade.

Signal priorities for 1183 focused on:

- Establishing avalanche detection
- Continued testing of system function.
- Minimize or eliminate false alerts.
- Simplify the system for maintenance.

Pursuing system priorities led to development of a computerized hardware component of the system, the Human Machine Interface (HMI) along with supporting software.

To reduce false-positive sensor detection, algorithms were programed into the HMI software which eliminated sensor sensitivity to vibration and required actual tipping of sensors for detection of movement.

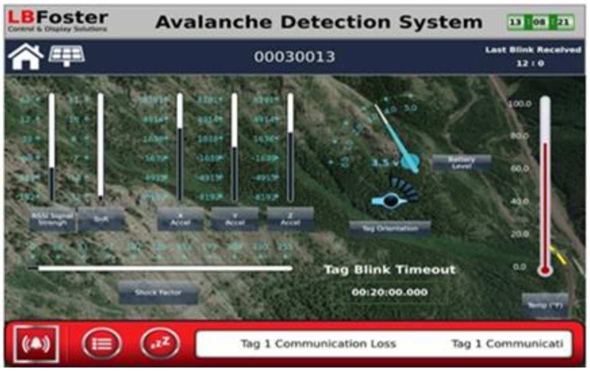

Photo 5: HMI display created by LB Foster.

The HMI hardware communicates via radio with multiple Gateways of individual sensor-based systems and provides a graphical representation of each system's status related to metadata such as battery voltage, signal strength, temperature.

Status warning alerts are also generated for each system by the HMI software. For detection of movement, the HMI will display a critical alert when two (2) or more sensors are tilted more than 30° and an alert will also be displayed when a critical system failure occurs, such as when multiple sensors are not reporting.

Status is displayed in real-time and electronically accessible remotely (Photo 5) or from a field-based monitor onsite (Photo 6). The onsite HMI monitor is stationed in a heated bungalow and outside avalanche prone terrain.

Photo 6: An LB Foster HMI onsite monitor.

4.3 Phase 3, 1183 System Install & Protocol

With the completion of monitoring hardware and software, Signal focused on a permanent install of the 1183 sensor array (Photo 7) and creating instructional policy for BNSF Dispatch, the Signal Operations Center (SOC), and Maintainers.

1183 hardware and foundational structure included:

- 12 rugged tip-over towers with sensors.
- Concrete tower foundations with modular tower connection points.
- New mounting hardware for sensors.

Photo 7: 1183 tower and sensor array

Protocol has been established for the 1183 system where if an indication occurs, dispatch will notify train crews of a potential avalanche event, train speeds will be reduced to not exceed 32 km/hour (20 miles/hour) in the vicinity of 1183, and wil be prepared to stop for any obstructions on the track. Train crews are reminded to regulate speed where visibility is limited (ex. curvature of track, lighting, weather, etc.) and must report to the dispatcher the conditions encountered within these limits.

For system-error indications, Dispatch will notify the SOC of a potential failed sensor/battery and they will dispatch a Maintainer to conduct needed repairs.

Maintainers and other BNSF technicians have received instructions and training on how to inspect the system prior to, during, and after the winter season. This includes inspecting the tower's structural integrity, changing out batteries, and verifying all sensors are reporting and can alert when tilted.

As of the 2022-23 season, the 1183 system is performing as designed. However, important to note, the system has not yet been impacted by an actual avalanche event.

5. LOOKING FORWARD

BNSF is currently reviewing and assessing potential opportunities to install a system like that in 1183 at other avalanche prone locations in the Program Area.

Additionally, BNSF is evaluating how the existing system technology may be implemented to enhance/replace other detection systems at slump, slide, and rock fall locations. However, adjusting the existing system components for these new applications would be a multiple year project to vet system technology and establish objective confidence in system reliability.

The authors of this paper hope to generate further interest amongst professional peers regarding these sensors and their use for avalanche debris detection.

ACKNOWLEDGEMENTS

All aspects of system design, development, and implementation are credited to BNSF and LB FOSTER. Contributions to the production of this paper were a cooperative effort between the BNSF Signal Department and Program forecasters employed by David Hamre and Associates LLC.

REFERENCES

Clark, A., Hamre, D., Steiner, T.: BNSF Avalanche Safety Program Review, David Hamre & Associates LLC., BNSF Railway, Fort Worth, TX., Internal File Report, 21 pp., 2022

LB Foster.: Avalanche Detection System: PDF, Open File Report, 4 pp., 2019.

Steiner, T., Clark, A. 2017-18 BNSF Avalanche Safety Program Annual Report, BNSF Railway, Fort Worth, TX., Internal File Report, 2017-18, 17 pp., 2018.

Steiner, T., Clark, A. 2016-17 BNSF Avalanche Safety Program Annual Report, David Hamre & Associates LLC., BNSF Railway, Fort Worth, TX., Internal File Report, 2016-17, 23 pp., 2017.