AVALAUNCHER TARGETING FOR MOBILE GUN PROGRAMS

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ABSTRACT: The paper merges the theory of the avalauncher targeting model developed by DuVall and Jenkins (2008) and the practice of avalanche mitigation with a mobile avalauncher. For two seasons we used an avalauncher gun to aid control of several high frequency avalanche paths affecting two high mountain passes in the Omineca Mountains of British Columbia Canada. The program required control of several start zones requiring multiple firing positions. Short daylight hours and consistent extreme winds constrained our avalanche control options. An avalauncher gun was fixed into a truck bed and standard firing locations were established. The most important avalauncher risk is accuracy. Overshooting a ridgeline or missing a start zone creates issues confirming detonations and increases explosive costs. Selecting effective target parameters requires an expert's subjective perspective and objective measurements. Target acquiring initially included field-based measurements and subjective estimates for establishing firing values. To improve accuracy and reduce uncertainty we implemented the targeting model into a field operable spreadsheet that provided objective feedback and firing value options into the work routine. It was determined that both subjective and objective processes are important in working with the avalauncher in a mobile context. The developed work routine was observed to improve confidence, accuracy and safety margins. This experience reinforced the avalauncher as a viable option for avalanche control and offers strategies to reduce uncertainties for future users and projects.

KEYWORDS: Avalauncher, targeting model, process feedback

1. INTRODUCTION

Effective avalanche control requires reliable start zone access. Options in difficult or inaccessible terrain avalanche control options are often constrained by operational resources or unreliable due to weather conditions. Helicopter explosive control provides excellent start zone access. However, this method is relatively expensive and requires decent weather conditions. Worker safety or time constraints may limit the effectiveness Hand-thrown explosive control. Remote avalanche control systems (RACS) provide reliability and start zone access, the installation and capital costs limit their application. Like RACS, artillery control provides reliable access to start zones, but materials are often unavailable. The avalauncher is a unique tool that projects explosives into remote locations for avalanche control.

When applied in a mobile context, confidence in acquiring targets and ensuring safety for surrounding areas can be challenging due to changing target parameters. Accurate targeting requires a process that can check or verify firing pressure against the estimated inclination and barrel pressure values.

In 2008 DuVall and Jenkins authored an important paper for avalauncher users. Their work outlined the physics involved in avalauncher projectile flight and provided a model capable of providing targeting values based on gun dimensions and field measurements. For established avalauncher control programs the targeting model offers opportunity to test proven values and provide guidance for new targets. For mobile avalauncher programs the tool offers the opportunity for objective feedback in the work routine by improving accuracy thereby improving safety.

This paper provides a case history of how we applied DuVall and Jenkins's targeting model into a mobile avalauncher program. The case history describes the program's constraints and requirements. A key lesson learned for the program's procedures included the importance of combining subjective estimation with objective feedback. This resulted in improved confidence in applying the avalauncher as a viable option for avalanche control.

2. AVALAUNCHER BACKROUND

Development of the avalauncher started in 1961 and operationally in use around 1964 (Brennan 2006). It was designed by Frank Parsoneault and the key technology includes a pneumatic valve that quickly releases a compressed gas capable of pitching a projectile. Monte Atwater worked closely on the research and design of the avalauncher technology crafting a tool that could project an explosive for the purpose of avalanche control (Atwater, 1971).

The principles of aligning an avalauncher gun for firing include.

1. Securing the gun at a specific location.
2. Setting the gun barrel azimuth and incline relative to a target.

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3. Establishing the appropriate firing pressure for compressed propellent.

Established control programs typically fix the avalauncher in a specific location(s). Targeting may include field measurements and subjective estimation through trial and error until confidence firing values are obtained. Once dialed in, target name, azimuth, firing pressure, and barrel incline are recorded into a firing log. The firing log allows avalauncher operators to repeatably select a start zone with reasonable accuracy. While operational avalauncher procedures may vary, these are the typical processes in use.

For mobile avalauncher gun programs a firing log may not exist, or parameters may be always changing according to adjustments of the avalauncher location or its targets. Estimation of firing parameters may be a constant task adding complexity to the work with uncertainty for target accuracy.

3. AVALAUNCHER FUNDAMENTALS

DuVall and Jenkins highlight key points that all avalauncher users should be aware of, including the importance of a knowledgeable understanding of the target's firing parameters and the projectile flight tendencies.

In practice avalauncher operators should be knowledgeable of the target parameter measurements as well as the effects of barrel incline and firing pressure adjustments on the projectile flight trajectory and targeting implications.

The model allows the operator to estimate the projectile flight paths for various target requirements. This allows for more spreadsheet trial-and-error targeting and fewer explosives used for targeting.

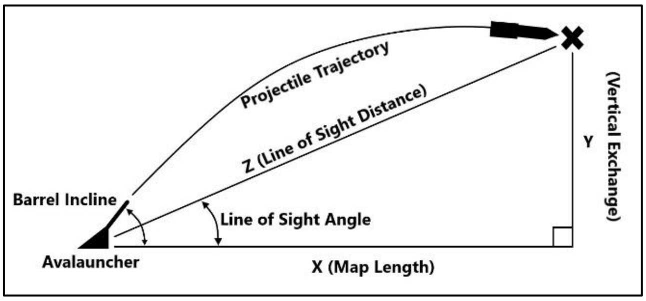
Adjusting the barrels inclination and firing pressure can manipulate the avalauncher projectile's flight path to create a more perpendicular impact, theoretically reducing misfires.

With an understanding of the targeting parameters, avalauncher users can expand their developing experience to include awareness of target distances and the relationship of barrel incline and pressure to acquire the target. This is viewed as essential knowledge for using an avalauncher, especially for a mobile program.

4. CASE HISTORY

In 2020 our avalanche risk assessment for a mineral exploration project identified several avalanche paths scattered through the remote resource road network. The program required 24-hour forecasting and avalanche control to maintain the winter roads. The mineral exploration camp was at the end of resource road. Minimizing road closures was critical for the operations logistics and maintaining emergency access.

Figure 1 shows the relevant target parameters that avalauncher operators should be aware of. The line-of-sight distance and line of site angle can be measured with a rangefinder. Alternatively, a topographical map can provide the vertical exchange and map length.



For two seasons (2020/21 to 2021/22) we used the avalauncher gun for avalanche control of avalanche paths threatening the resource road through two high mountain passes. The pass elevations included 1785 and 1848 m with surrounding summits between 1890 to 2030 m. The project area had a thin continental snowpack with prevalent wind slab avalanche problems. Helicopter control was an option, however at 57° North the reduced daylight hours limited the window of acceptable flying conditions. The program's most demanding objective included control of the roadside slopes to facilitate snow clearing operations.

The highest frequency area spanned approximately 4 kilometers through the two mountain passes. Three avalanche paths comprised the most active terrain required daily control due to extended periods of sustained strong to extreme winds continuously reloading start zones above the resource road. Four additional avalanche paths, each with its own firing location, required less frequent control.

By functioning regardless of weather conditions, the avalauncher improved the effectiveness of the control program. In total 26 new targets were identified with variations depending on the snow distribution. Throughout two seasons of work, there were 48 days of avalauncher control firing 194 units. Avalauncher control triggers 37 events impacting the resource road. Other methods of avalanche control included slope cutting with machinery, helicopter control, hand charging, and case charging. In total, the program saw 178 avalanches on the road, including all controlled and natural events.

Figure 2: Image of truck mounted avalauncher with Path 20 in the background. 3 avalanches triggered by the avalauncher are observed with terminations on the road.

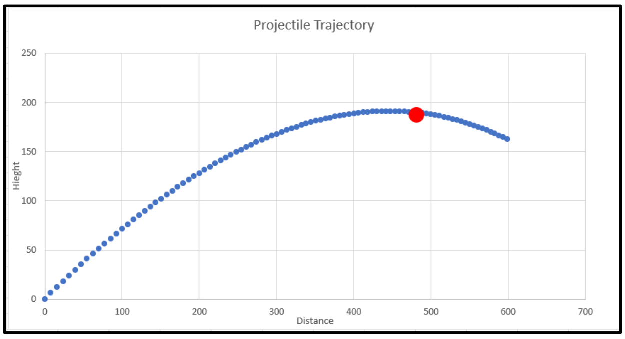


Figure 3: Image of targeting model output where the dot represents the target, and the blue line represents the calculated projectile trajectory. This visual aid was internally developed and allowed for the user to view the requirement to either increase or reduce barrel inclines and firing pressure values to obtain the target.

In the first season of use avalauncher targeting relied on the subjective estimation of an experienced avalauncher operator. Targeting estimation strategies for building a firing log included historical experience, distance measurements with a range finder or digital mapping, inclinometer, trial-and-error, and adjustment. While the subjective estimation and previous experience of an experienced operator was a reasonable strategy, the firing procedure was lacking for avalanche technicians with various levels of experience.

To improve our firing procedure, we implemented DuVall and Jenkins targeting model to address this knowledge and experience gap and assist with acquiring new targets or adjustments from the firing log targets. In 2008 the targeting model was presented for use in a spreadsheet but noting the limitation of requiring a computer. We formatted the model for use on a smartphone spreadsheet allowing the avalanche technician to check their field firing parameters against the theoretical parameters of the targeting model. This procedure improvement offered objective feedback to the avalauncher operator and provided guidance for adjusting the firing parameters to make target adjustments or calibrate new targets.

While the model provided an objective perspective it is important to note variances to accuracy were observed. Our general observations of the targeting models output to actual firing pressure varied up to 10 psi. Observed variances of the models firing pressure values were noted below actual values required, suggesting the target model represented less projectile drag than observed. This could be explained by changes in avalauncher projectile construction. The higher-pressure variances were also linked to greater flight distances implying increasing discrepancies with longer flight trajectories

It is likely that some of the observed variances were linked to input errors. It is important to account for the user errors that are inherent with estimated measurements when comparing to actual targeting measurements. After one season of operational use, the targeting model was a positive addition to our firing procedure. The model consistently provided accurate pressure values within 10 psi of our targets. We consider this to be higher accuracy than reliance solely on subjective estimation of firing parameters.

While noting reasonable accuracy of the targeting model, subjective estimation and adjustments remained essential for avalauncher use. Deliberate adjustments to values that either ensured safety margins such as targets close to ridgelines or modifying a proven placement to adjust for snow pattern changes are examples. In addition to using the targeting model and applying experience-based adjustments, recording a firing log is of utmost importance. The firing log is essential for referencing historical observed firing values that can also be considered for new target sighting.

Through repetitive firing experience, our confidence in target values improved, reducing our dependency on using the targeting model. Upon reflection the targeting model improved our firing and targeting and will not be omitted in our future work. By integrating the targeting model into our standard mobile avalauncher practice we found the following benefits:

1. Review of all targeting parameters improves the formation of data relationships for avalauncher users.
2. Estimates made can always be verified or contested by objective feedback.
3. Integrating the tool as a standard practice, the work routine becomes more consistent, trainable, and transferable between technicians.

5. LESSONS LEARNED

Avalanche mitigation strategies ideally serve the best interest of the client. For programs in remote locations and short-term durations mitigation options that provide flexibility, and lower operational costs may be appropriate. For this case study the avalauncher proved itself to be a highly valuable mitigation tool allowing for a reduced dependency on helicopter use and saving on capital investments for longer term and comparably cost prohibitive solutions. The avalauncher demonstrated itself to be an effective and viable tool that warrants consideration by consultants.

To safely optimize the working environment when using an avalauncher, using systems that support both subjective and objective inputs for the work are valuable. By applying the targeting model into our work routine our team observed an unexpected improvement in system awareness and opportunity for critical objective input feedback for firing value calibration. This is viewed as a major contributor to improved safety in avalauncher use.

For the mobile avalauncher, defining the avalauncher's accuracy is an important part of calibration. Whenever possible, targeting onto broad general terrain features where exploding charges can provide representative stability data is important. If targets can be general in terms of triggerable areas, the combined use of the targeting model, a firing log and subjective estimation can support accurate and effective avalauncher use.

Additional tools (including the DuVall and Jenkins targeting model) provide an opportunity to *refine* how the avalauncher gun is used. By making certain processes for acquiring measurements a standard action, better awareness of targeting variables can be achieved. For mobile gun programs adopting tools such as a sighting scope, range finder, remote firing system and firing value references can make the work sequence better informed, accurate and safer.

Figure 4: Image of a mobile avalauncher from the Atwater Archives.

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