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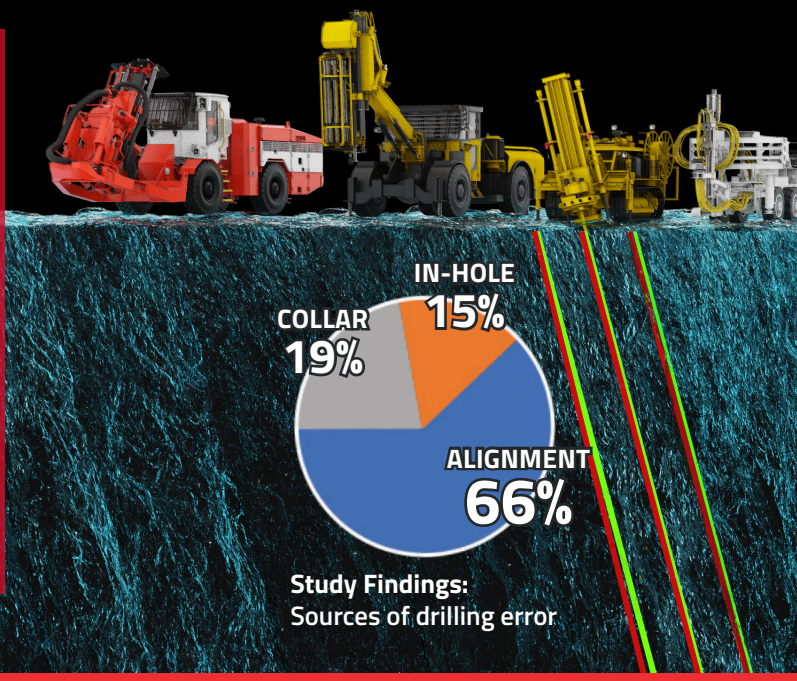
> Average deviation at the toe across all 10 sites was **6.8% (1.7ft over a 24ft hole)** - well outside 'best practice'.
>
> **66%** of the error at the toe was due to **alignment error** - indicating current drill setup processes are not only inaccurate, they are also highly inconsistent (7.3% Standard Dev.)
>
> There exists a significant opportunity for a step-change improvement in drilling accuracy and stope performance - **by reducing alignment error.**

**Ryan Stimpson,**
**Minnovare, Head of Engineering**




**Study Findings:**
Sources of drilling error

# CANADIAN BLAST-HOLE SURVEY STUDY

**Down-hole surveys** were conducted across 10 Canadian underground hard rock operations. The results have been analyzed to better understand typical drilling accuracy and the factors that result in blast-hole deviation. The data was further broken down by drill type (Boom, Horse-Shoe, Buggy, Cubex).

| | |
|---|---|
| **LOCATION:** | Canada |
| **YEAR:** | 2019 - 2020 |
| **INDUSTRY:** | Underground Mining, Long-Hole Stoping. |
| **CLIENT:** | Multiple |
| **FOCUS:** | Production Drilling |
| **DRILL TYPE:** | Boom, Horse-Shoe, Cubex, Buggy |
| **SOLUTION:** | Production Optimizer |

## THE STUDY:

Survey data was captured from a total of 10 underground mine sites across Canada between 2019 and 2020.

Across the 10 sites, four commodities are mined – gold (7), silver (1), copper (1) and nickel (1). All mines have narrow-vein ore bodies with the primary mining method being long-hole stoping.

Across the 10 sites, a total of 454 holes were drilled using the 'existing process' and then later surveyed. The average surveyed length of all holes was 24.2ft. The average number of holes drilled and surveyed at each site, was 45.

## EXISTING PROCESS:

'Existing process' refers to the required steps a drill rig operator must follow to set up a drill using conventional systems and processes.

The existing process is dependent on numerous variables which can influence set up accuracy.

This includes the marking of laser lines, rig alignment to those lines, ensuring the rig is leveled and operator skill/judgment during drilling.

Across the 10 sites, there were four 'types' of long-hole production drill used – Boom, Horse-Shoe, Cubex, and Buggy.

> **The existing process relies on multiple variables which create drilling error - regardless of whether you're drilling with a Boom, Horse-Shoe, Cubex or Buggy drill.**

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## BLAST-HOLE DEVIATION EXPLAINED:

Blast-hole deviation is measured as the extent to which the toe-point of a blast-hole deviates from the plan. Blast-hole accuracy is widely understood to be key to optimal blasts, defined as **minimized dilution**, **maximized recovery** and **optimized fragmentation**.

Most underground drill and blast operations have targets in place regarding acceptable levels of deviation, commonly referred to as 'tolerance'.

Holes drilled are classified as either 'within' or 'outside' tolerance, with holes sufficiently outside tolerance potentially requiring re-drilling – a further cost of production.

There are three factors that contribute to blast-hole deviation; **collar** error (due to collar location error), **in-hole** deviation (due to ground conditions and operator skill/judgment during drilling) and **alignment** error.

Consistently inaccurate drilling causes sub-optimal blasts and as a result, poor stope performance.

This includes reduced ore recovery, over/under-break, dilution and lost drilling productivity as a result of re-drills - increasing stope cycle time.

## METHOD:

All holes were set up using the **existing process**. All holes were surveyed using non-magnetic survey instruments.

The alignment error was calculated by measuring the hole trajectory at the first 6ft (1.8m) of the survey.

The actual collar position was measured by the mine surveyor and compared to the plan.

The error at the toe and in-hole deviation was measured by comparing the surveyed hole trajectory and hole position to the plan.

## FINDINGS ACROSS ALL SITES:

**Inaccurate Drilling:** Across the 10 mines, average toe deviation was **6.8%.** Over the average hole length (24.2ft), this equates to an error of **1.7ft** (52cm). Average toe deviation is therefore well outside industry 'best practice'.

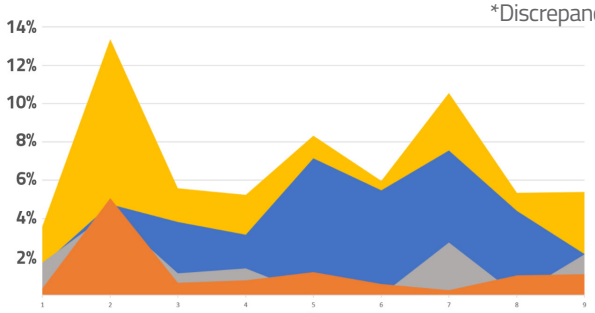
**Sources of Error:** The majority of toe deviation **(66%)** was due to alignment error - indicating flaws in the existing process for setting up the drill were primarily to blame for overall inaccuracy. Around 19% of the error at the toe was due to collaring error and 15% due to in-hole deviation.

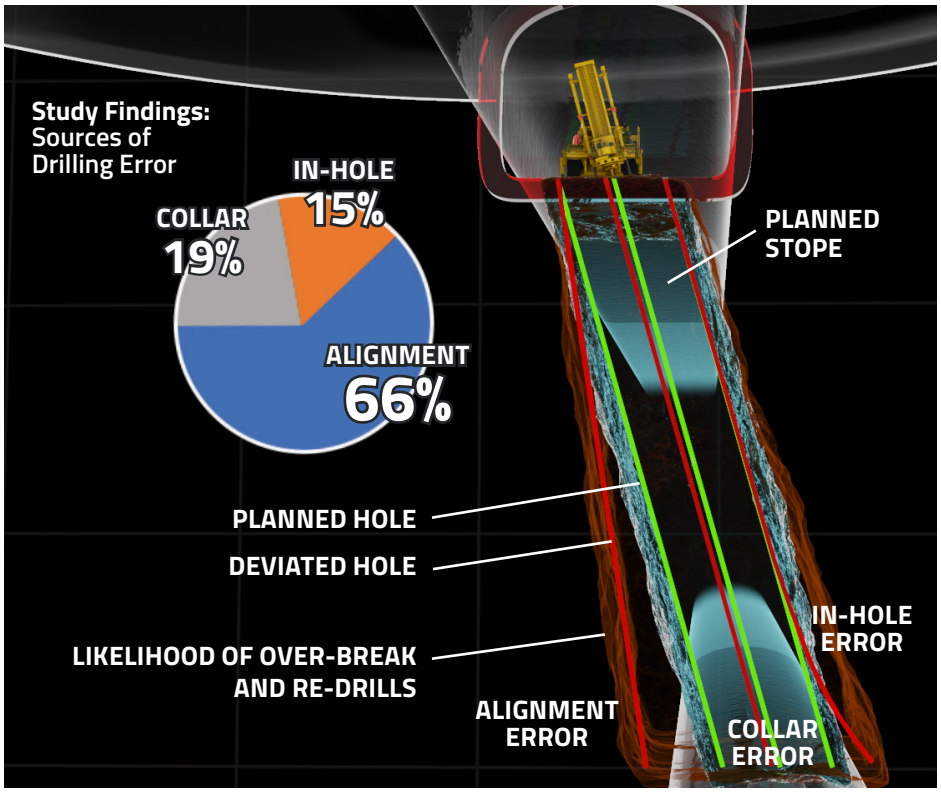
**Inconsistent Drilling:** The stand dev. in alignment error was 7.3% across drill types, indicating highly variable set up accuracy irrespective of drill.

**The Result:** Inaccurate and inconsistent drilling can result in poor stope performance. (re-drills, over/under-break, reduced recovery).

| | All Holes | Collar Error Avg | Alignment Error Avg | In-Hole Error Avg | Total (Toe) Deviation Avg* |
|---|---|---|---|---|---|
| All 10 Sites | 454 | 1.4% | 4.5% | 1.0% | **6.8%** |

*Discrepancies in 'Total' due to rounding errors



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| Drill Type | **Collar** Error Avg | **Alignment** Error Avg | **Alignment** Std Dev | **In-Hole** Error Avg | **Total** (Toe) Deviation Avg* |
|---|---|---|---|---|---|
| Cubex | 1.5% | 4.5% | 9.4% | 1.6% | 7.4% |
| Buggy | 1.5% | 5.3% | 6.6% | 0.6% | 7.3% |
| Horse-Shoe | 0.8% | 2.2% | 3.0% | 1.1% | 4.0% |
| Boom | 0.8% | 3.1% | 1.4% | 1.6% | 5.3% |
| **Average** | **1.4%** | **4.5%** | **7.3%** | **1.0%** | **6.8%** |

*Discrepancies in 'Total' due to rounding errors

**INACCURATE:**
**6.8%** AVG HOLE DEVIATION ACROSS ALL 10 SITES

**10 MINE SITES,**
4 DRILL TYPES,
454 HOLES,
AVG LENGTH: 24ft

**INCONSISTENT:**
**7.3%** STD DEV. IN ALIGNMENT ERROR, ALL DRILLS

**MINING METHOD:**
NARROW VEIN, LONG-HOLE STOPING

**MAJOR CONTRIBUTOR:**
**66%** DUE TO ALIGNMENT ERROR

**DRILL TYPES:**
BOOM, CUBEX, HORSE-SHOE, BUGGY

## BREAKDOWN BY DRILL TYPE:

Of the four drill types, Cubex was the most common, drilling 35% of the total holes.

Both the Cubex and Buggy drills delivered the most inaccurate drilling - 7.4% and 7.3% deviation at the toe respectively.

Horse-Shoe and Boom proved the most accurate with 4.0% and 5.3% average deviation at the toe respectively - although still well outside 'best practice.'

However, across all drill types, **alignment error proved to be the biggest contributor to total (toe) deviation**. For the Cubex alignment error attributed 61%, the Buggy 73%, the Horse-Shoe 55% and the Boom 58%. The analysis therefore shows... that existing drill setup processes, not drill type, represent the most significant factor leading to highly inaccurate and inconsistent drilling outcomes.

In conclusion, a significant opportunity exists to improve drilling accuracy and consistency across all drill types - by reducing alignment error.

| Drill Type | **Alignment Error Contribution %** |
|---|---|
| Cubex | 61% |
| Buggy | 73% |
| Horse-Shoe | 55% |
| Boom | 58% |

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## THE SOLUTION:

Minnovare's **Production Optimizer** is an advanced hardware / software system that is applicable to all production drill makes and models.

The system **eliminates up to 70% of error at the toe** by removing multiple variables from the existing setup process that result in inaccurate and inconsistent drilling, including;

Laser line mark-up, alignment to the laser lines, drill leveling, multiple inclinometer calibrations, wear and slack in the drill.

**The Production Optimizer simplifies the setup process down to a single tolerance - between the drill rod and the collar.**

Reducing these variables results in highly accurate, consistent drilling, which in turn delivers;

**Less re-work**, **reduced ore-loss** (under-break) due to inaccurate drilling and **reduced costs** associated with re-access and dilution/waste. The simplified process also leads to an **increase in stope turnover**, with more time spent drilling.

The technology enables mines to 'do more with the same' - increasing productivity, without adding additional drills. Finally, the system uses digital drill plans and plods to deliver real-time accuracy and accountability for both engineers and drillers.

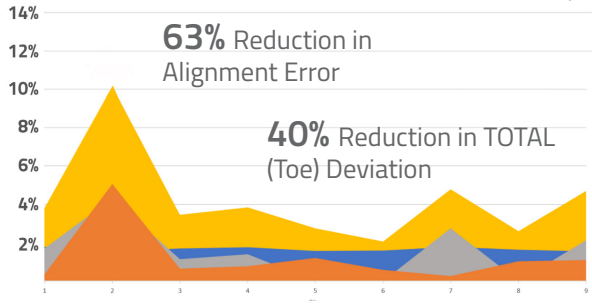
PRODUCTION™ OPTIMIZER

Reduce deviation.
Reduce dilution.
Increase recovery.

**Applying average results achieved with existing Production Optimizer clients (currently over 30 underground mines), to the findings in this study, a 46% reduction in toe deviation could be achieved;**

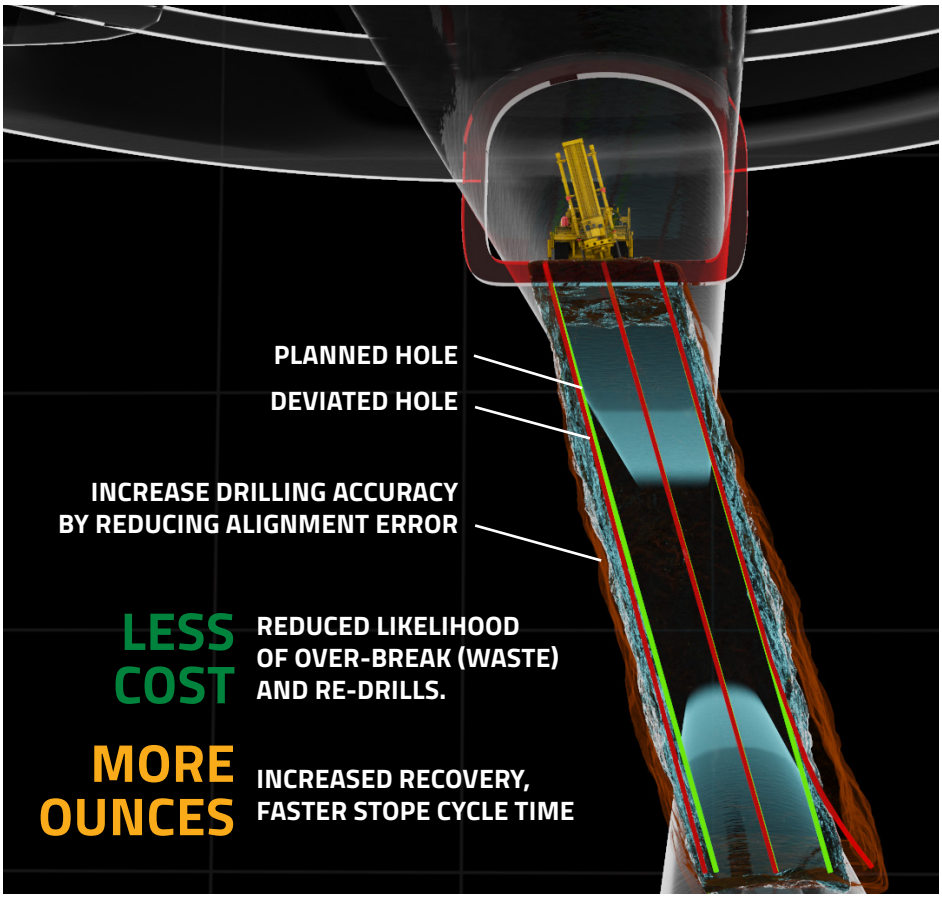
| | All Holes | Collar Error Avg | Alignment Error Avg | In-Hole Error Avg | Total (Toe) Deviation Avg* |
|---|---|---|---|---|---|
| All 10 Sites | 454 | 1.4% | 1.7% | 1.0% | **4.2%** |

*Discrepancies in 'Total' due to rounding errors




**By Site, w/Breakdown:**

- Total Average Deviation
- In-Hole Contribution
- Collar Contribution
- Alignment Contribution




## More Information

For more information on this case study and/or Minnovare technology, send us an email at **info@minnovare.com**

**CONTACT US:**
Viewing online? **Click here** to email us regarding this case study, or head to **minnovare.com/contact**

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Drill faster, cheaper, more accurately.