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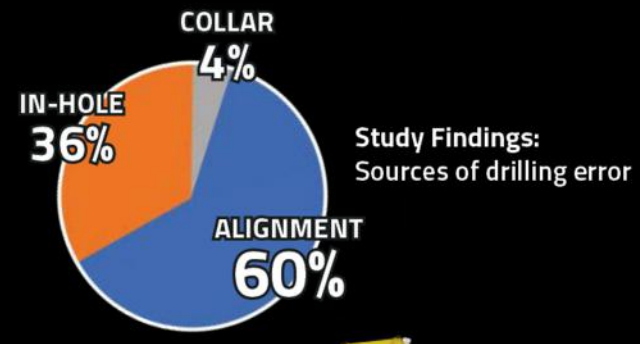

> Average deviation at the toe across all 17 sites was **5.8%** (1.4m over a 24m hole) - well outside 'best practice'.
>
> **60%** of the error at the toe was due to alignment error - indicating current drill setup processes are not only inaccurate, they are also inconsistent (2.7% Standard Dev. in alignment error).
>
> There exists a significant opportunity for a stepchange improvement in drilling accuracy and stope performance - **by reducing alignment error**.
>
> **Ryan Stimpson,**
> **Minnovare, Head of Product and Product Strategy**

AUSTRALIAN BLAST-HOLE SURVEY STUDY

Down-hole surveys were conducted across 17 Australian underground hard rock operations. The results have been analysed to better understand typical drilling accuracy and the factors that result in blast-hole deviation. The data was further broken down by rig type (Boom and Horseshoe).

LOCATION: **AUSTRALIA**

YEAR: **2019-2020**

INDUSTRY: **UNDERGROUND MINING, LONG-HOLE STOPING**

CLIENT: **MULTIPLE**

FOCUS: **PRODUCTION DRILLING**

RIG TYPE: **BOOM, HORSE-SHOE**

SOLUTION: **PRODUCTION OPTIMISER**

THE STUDY

Survey data was captured from a total of 17 underground mine sites in Australia throughout 2019 and 2020. Across the 17 sites, four commodities are mined – gold (16), zinc (1), copper (2) and nickel (1). Three of the operations are mining more than one commodity on site - resulting in the discrepancy in total sites.

All but one of the mines have narrow-vein ore bodies with the primary mining method being longhole stoping (13), followed by open stoping (3), and the remaining mine conducting sub-level stoping.

Across the 17 sites, a total of 2,408 holes were drilled using the 'existing process' and then later surveyed. The average surveyed length of all holes was 24m. The average number of holes drilled and surveyed at each site, was 142.

EXISTING PROCESS

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 17 sites, there were two 'types' of long-hole production drill used – Boom and Horseshoe.

> The existing process relies on multiple variables which create drilling errors - regardless of whether you're drilling with a Boom or Horseshoe rig.

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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 **minimised dilution, maximised recovery and optimised 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 redrills - 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 1.8m (6ft) 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 17 SITES

Inaccurate Drilling: Across the 17 mines, average toe deviation was 5.8%. Over the average hole length (24m), this equates to an error of 1.4m. Average toe deviation is therefore well outside industry 'best practice'.

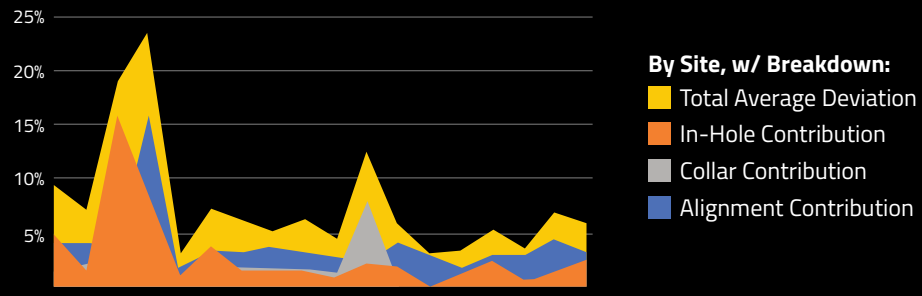
Sources of Error: The majority of toe deviation (60%) was due to alignment error - indicating flaws in the existing process for setting up the drill were primarily to blame for overall inaccuracy. Around 4% of the error at the toe was due to collaring error and 36% due to in-hole deviation.

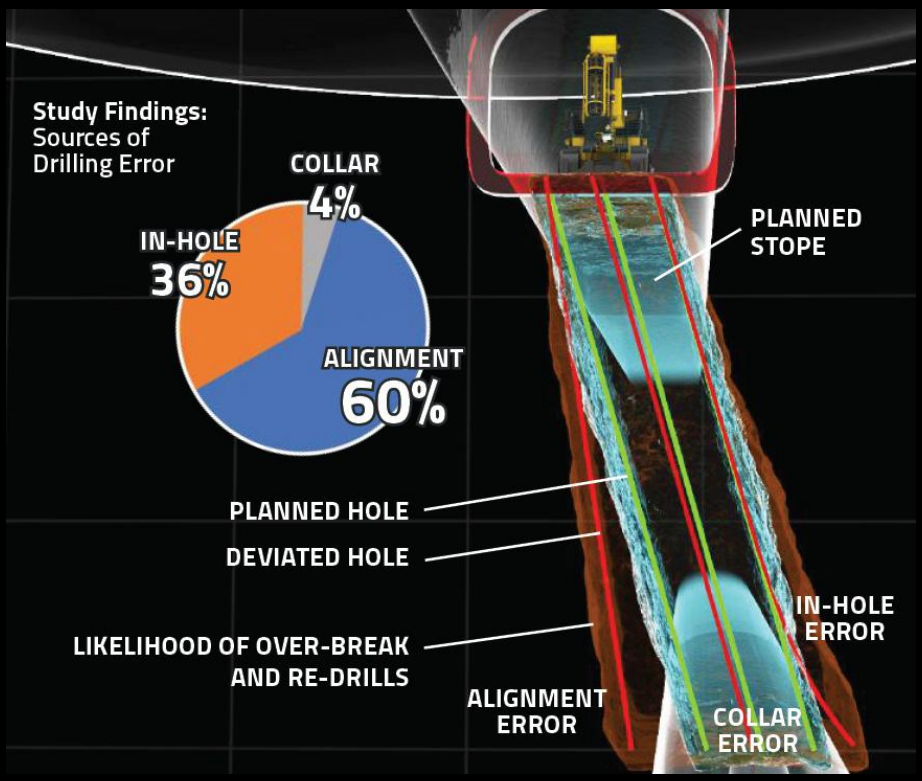
Inconsistent Drilling: The stand dev. in alignment error was 2.7% across drill types, indicating highly variable set up accuracy irrespective of rig type.

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 17 sites	2,408	0.3% ■	3.3% ■	2.4% ■	5.8% ■

*Discrepancies in 'Total' due to rounding errors





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EXISTING RIG SETUP PROCESS, NOT RIG TYPE, IS THE PRIMARY CAUSE OF POOR DRILLING:

Drill Type	All Holes	Collar Error Avg	Alignment Error avg	In-Hole Error Avg	Total (Toe) Deviation Avg*
Boom	0.65%	3.5%	3.3%	2.4%	6.2%
Horseshoe	0.05%	3.0%	2.1%	2.4%	5.4%
Average	**0.3%**	**3.3%**	**2.27%**	**2.4%**	**5.8%**

INACCURATE: 5.8% AVG HOLE DEVIATION ACROSS ALL 17 SITES

17 MINE SITES, 2 RIG TYPES, 2,408 HOLES, AVG LENGTH: 24m

INCONSISTENT: 2.7% STD DEV. IN ALIGNMENT ERROR, ALL RIGS

PRIMARY MINING METHOD: NARROW VEIN, LONGHOLE STOPING

MAJOR CONTRIBUTOR: 60% DUE TO ALIGNMENT ERROR

RIG TYPES: BOOM, HORSESHOE,

BREAKDOWN BY RIG TYPE

Of the two rig types featuring in the survey, the Boom was the most commonly used - with 13 of the 17 sites using this rig type. The Horse-Shoe however drilled the larger share of total holes 1,341 (56%) as opposed to the Boom's 1,067 (44%), despite only being in use at four of the 17 sites.

The Boom delivered the most inaccurate drilling, with an average of 6.2% deviation at the toe, compared to 5.4% for the Horse-Shoe.

Rig Type	Alignment Error Contribution %
Horseshoe	55%
Boom	56%

However, across both rig types, **alignment error proved to be the biggest contributor to total (toe) deviation**. For the Boom, alignment error attributed 61% whereas alignment in the HorseShoe accounted for 55% of total (toe) error.

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 rig types - by reducing alignment error.

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