Autonomous Surface Drilling

KGHM Robinson Mine

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Business Growth Manager –

Automation & Connectivity

Epiroc

Robinson Mine

Quick Facts

- Located in White Pine County, NV
- Names after Thomas Robinson, the prospector who discovered gold, silver, and copper here in 1868
- Three large open pits – Tripp-Vetern, Liberty, and Ruth (only active pit)
- 700 Employees
- 7,000 ft elevation
- Currently producing 125M lbs. of copper annually

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Insight

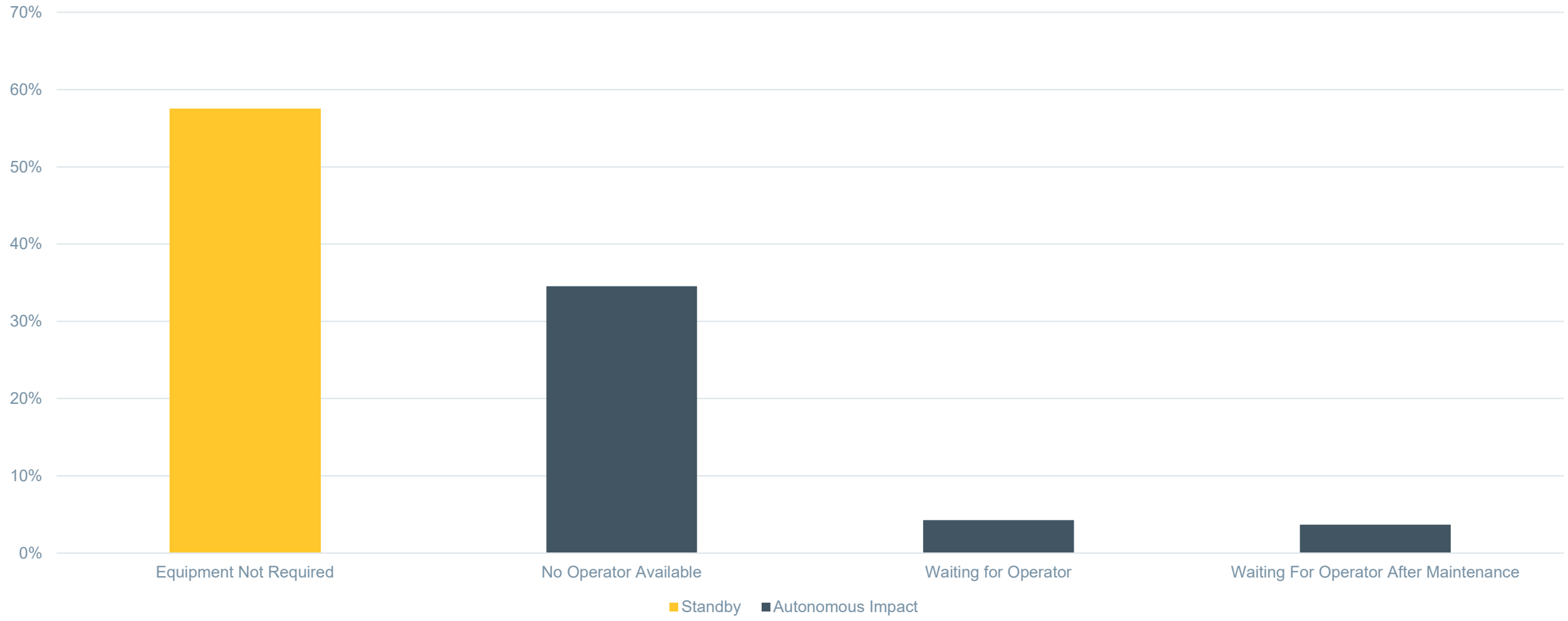
Project Problem Statement

- KGHM Robinson required the replacement of an aging drill fleet to meet their demanding production requirements
- Lowering the overall total operating cost of drilling to remain competitive against volatile copper prices.
- Skilled labor shortage in remote mining towns

Drill Cycle Utilization

Top Standby Activities

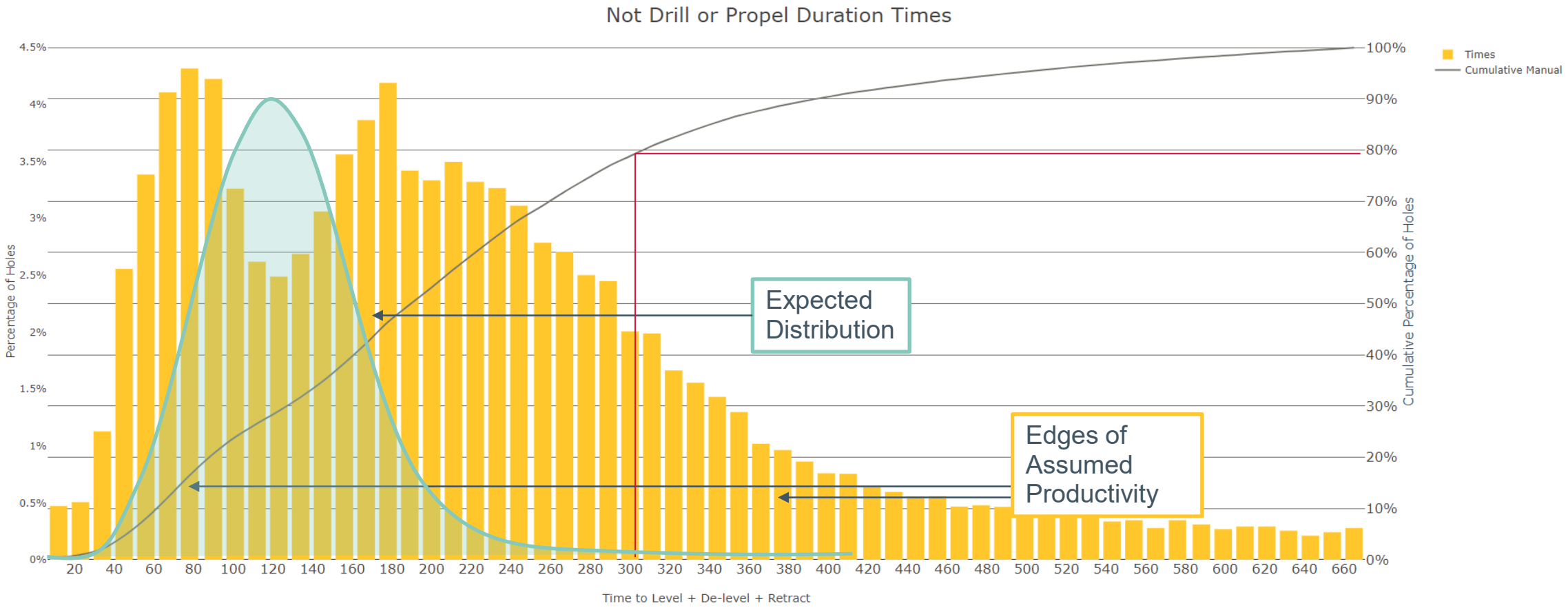
Fleet based



Calculated using supplied lists of stand by activities

In Cycle – Non-Drilling or Propel Times

Distribution – ‘Normal, Right Skewed’



- Distribution is expected to be normal, dependent on factors
- **Average time:** 186 s
- 20% tail (of all cycles) with greater than 300s non-drilling time per hole.

Calculated as difference between total cycle time and drilling time per hole*.

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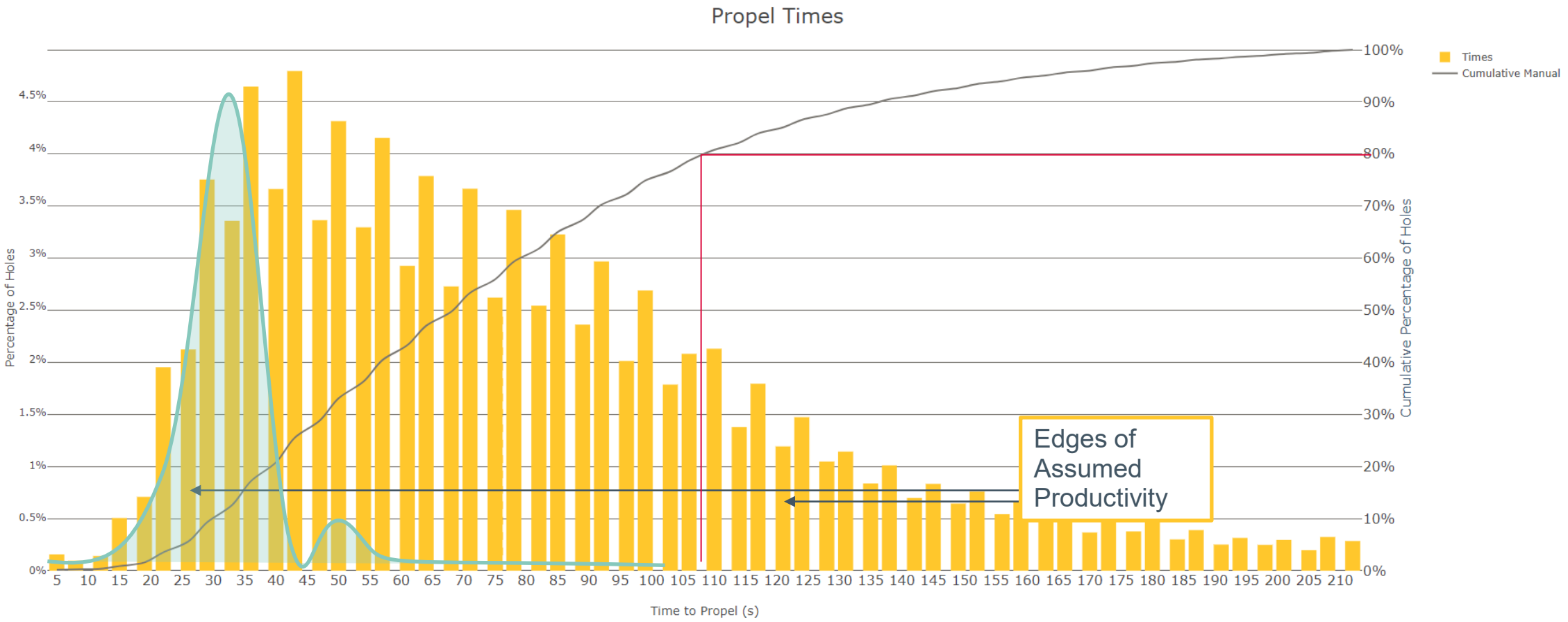
In Cycle – Propel Times

Distribution – ‘Normal, Right Skewed’



- Distribution is expected to be normal, factored by burden/spacing
- **Average time:** 67.5s
- 20% tail (of all cycles) with greater than 105s tramming time per hole.

Calculated as difference between total cycle time and drilling time per hole*.

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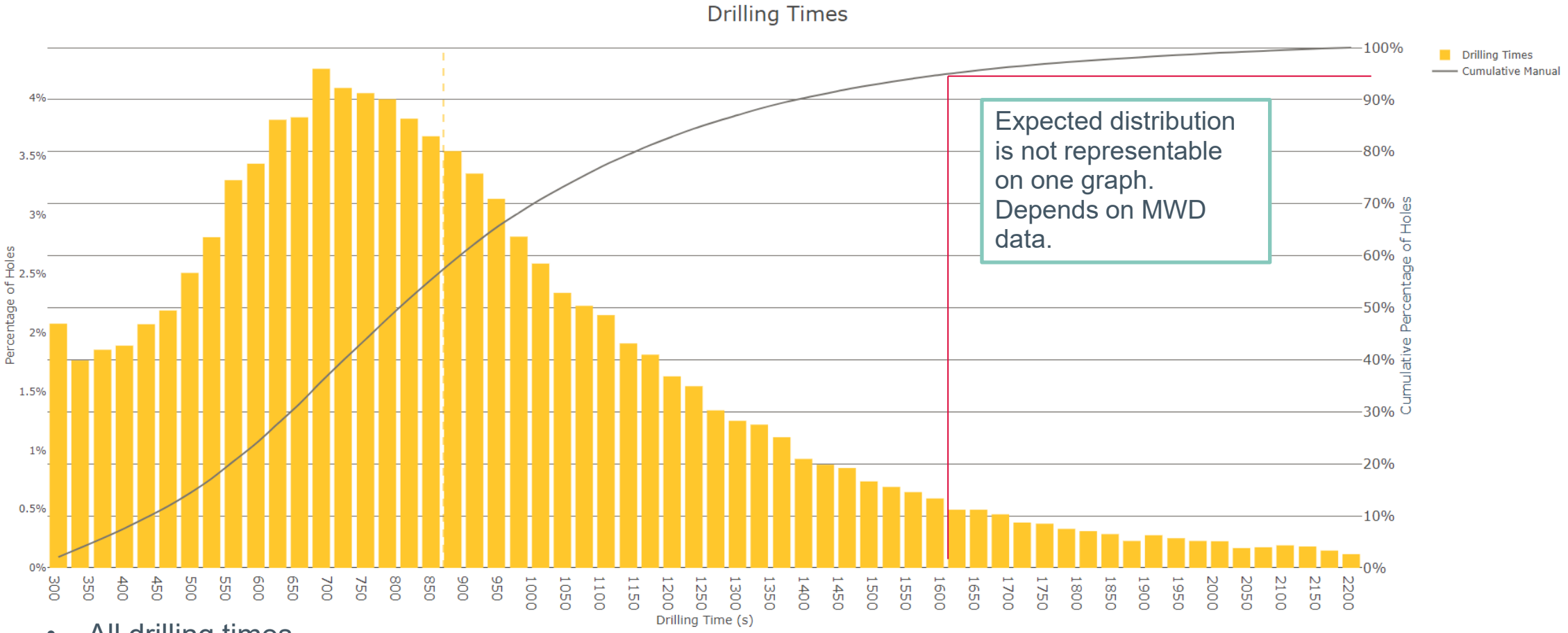
In Cycle – Drilling Times

Distribution – ‘Weibull, Right Skewed’



- All drilling times.
- Average time: 686 s
- 5% tail (of all cycles) with greater than 1618 s drilling time.

Calculated using supplied drilling times per cycle. Assumed to be time between drilling start and target depth reached.

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Overview

Drill Cycle Utilization

Part of Cycle	Lower Bound (s)	Median Time (s)	Upper Bound (s)	% Productive
Non Drilling Time	45	179	300	62%
Propel Time	24	63	105	66%
Drilling Time	140	694	1289	82%

Operator/Shift Sensitivity

Part of Cycle	Var (Total)	Var (Operator)	Var (Day/Night)	Var (Drill)
Full Cycle	334 s	104 s	1 s	10 s

- **Operators contribute towards 32% of the variance in cycle time.**
- **Equipment (Drill) contributes towards 3% of the variance in cycle time.**
- **0.3% variation due to time of day (night shift vs day shift)**

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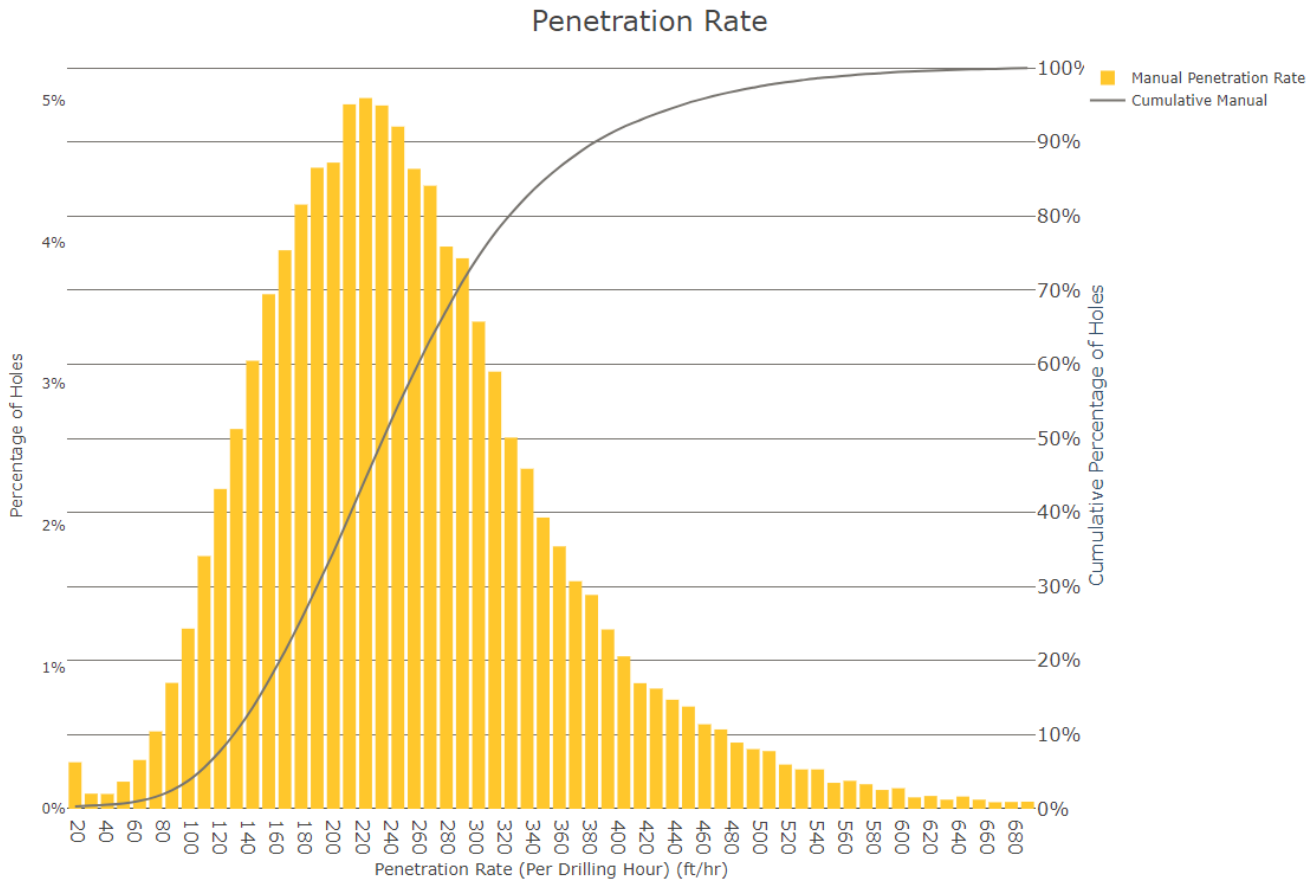
Drilling Performance

Penetration Rates

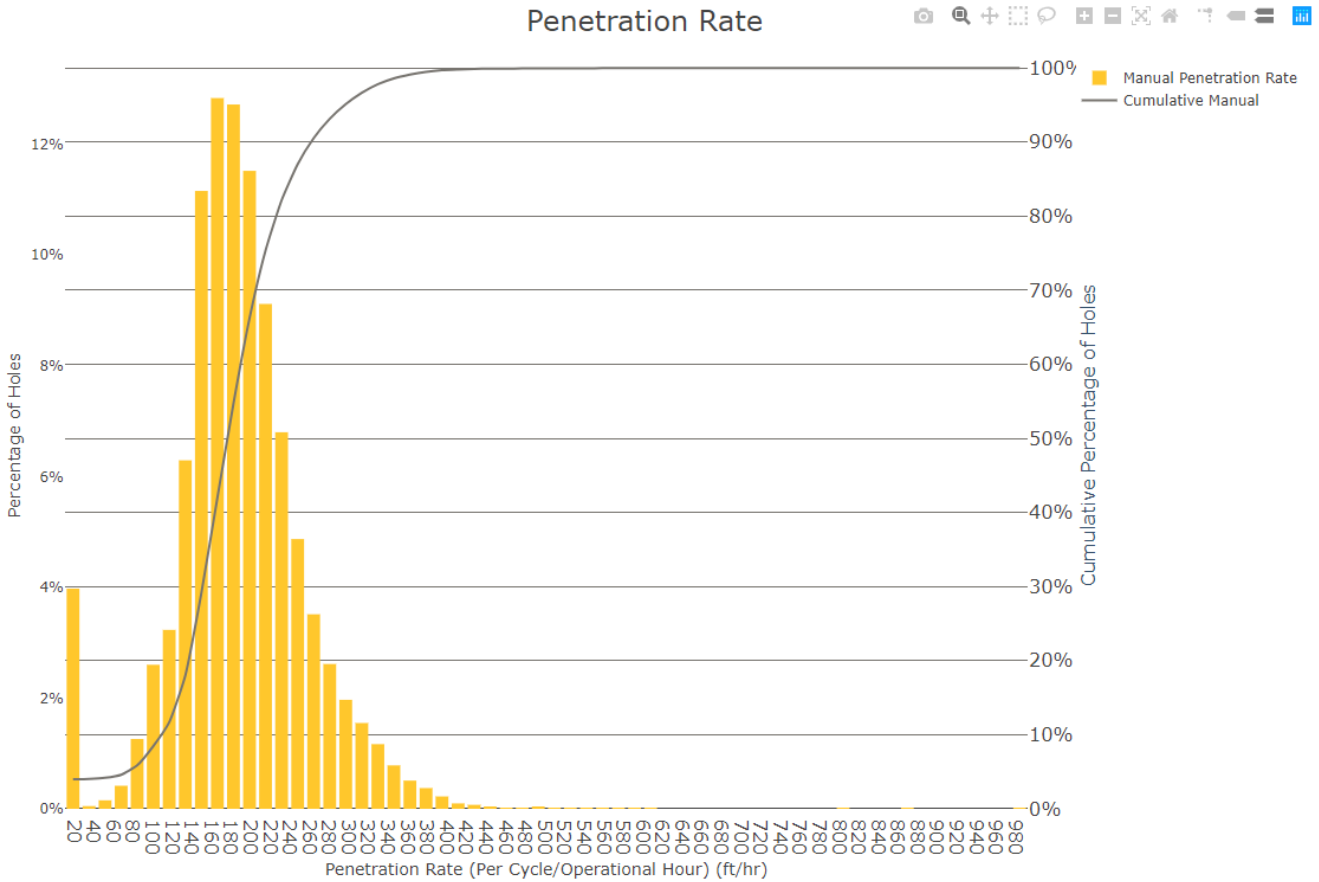
Per Drill Hour (ft/hr)



- Calculated using **productive** drilling time only.
- Measure of drilling effectiveness. Variance is likely due to ground conditions.
- Outliers (and non-productive time) removed using statistical relevance and MWD distributions.
  - Holes categorized by MWD groupings, and compared to distributions of penetration rates
- **Average 246.42 ft/hr**

Penetration Rates

Per Cycle Hour (ft/hr) - FTPOH



- Calculated as meters drilled over productive cycle time (drilling and non-drilling).
- Measure of full cycle effectiveness
- Cycles have been adjusted to remove non-productive time, so that it matches with reported productive utilization.
- Variation is due to ground conditions, as well as any further introduced variance due to groupings like operator.
- **Average 174.7 ft/hr**

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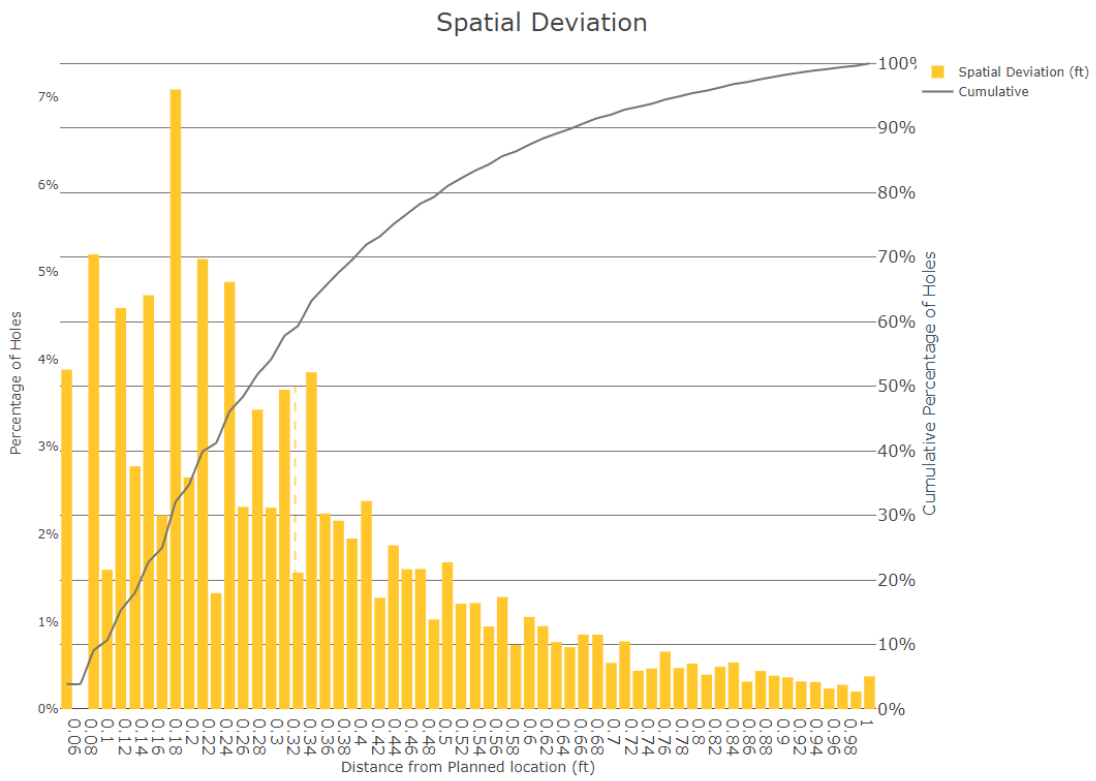
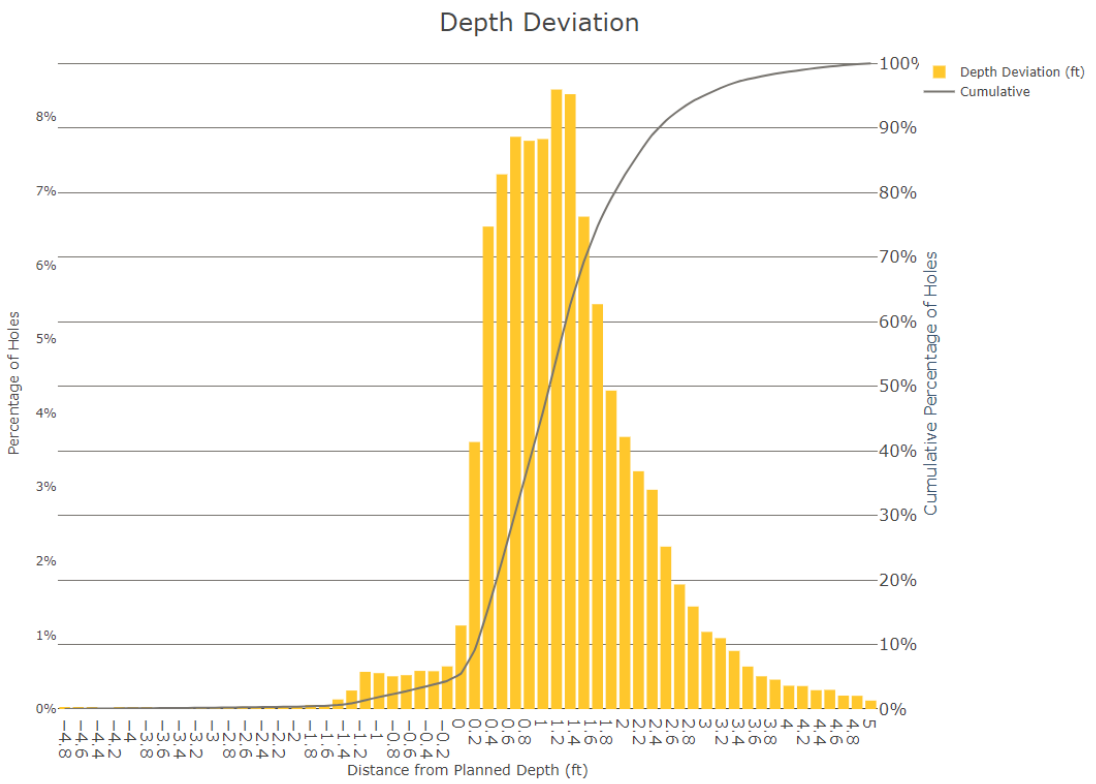
Hole Quality

Spatial Accuracy



Average	0.32 ft
>300mm	11 %

Depth Accuracy



Average	0.8 ft	1.29 m
>12” (U/O)	1.9%	54.7%

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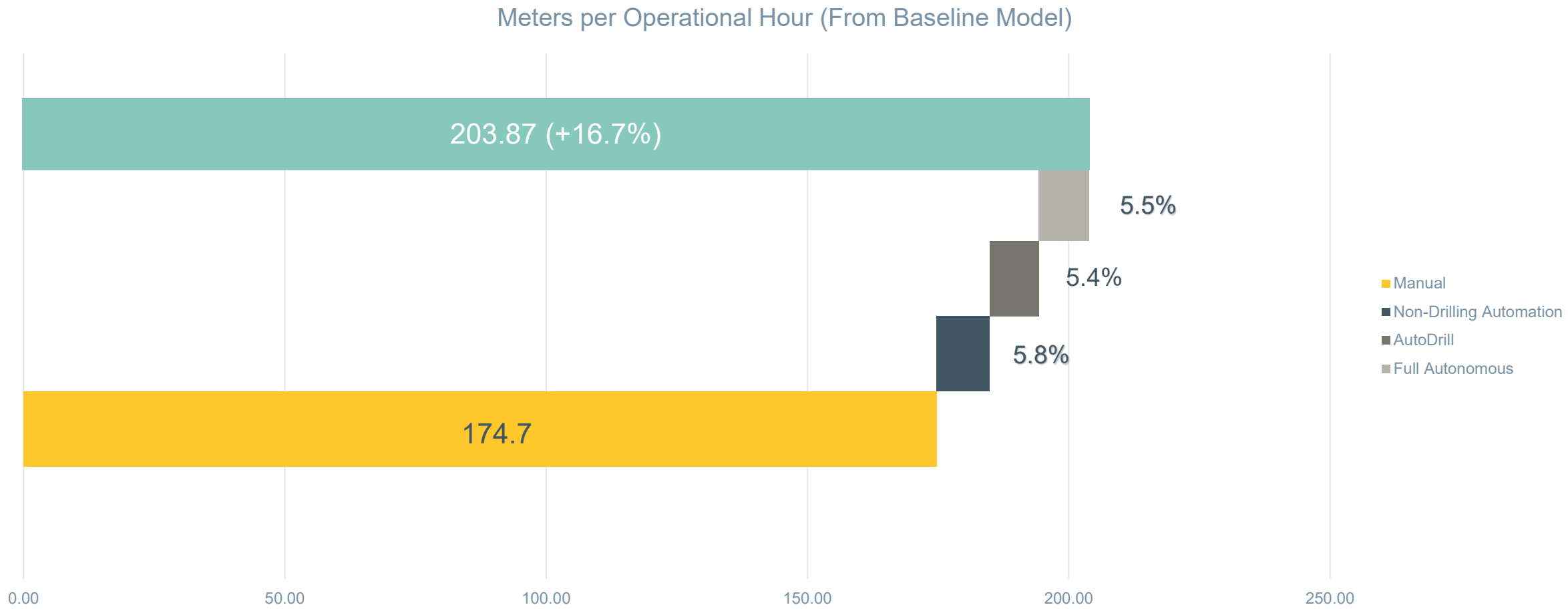
Autonomous Model

Assumed Increase in Productivity (of Utilized Time)

Autonomous Model

Expected Increase - MPOH



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Implemenation

Robinson Insight Example Cont'd

Once the contract was finalized, we entered the planning phase of the Automation Project Blueprint. Each KPI was defined with an agreed calculation method. A strategy was put in place to address the necessary changes to people and processes in order to achieve the desired results.

Keys to success

- Infrastructure
  - Assessed and ready
- Project Champion
  - Identified with clear KPIs
  - Communication
- On-site Support & Expertise
  - Maintaining and autonomous machine

KPI	Definition	Calculation	Baseline	Target
A. Automation System Availability Percentage	Percentage of time the drill automation is available for drilling.	$\left(\frac{\text{Total Nominal (Calendar) Time} - (\text{Scheduled event} + \text{Unscheduled event})}{\text{Total Nominal (Calendar) Time}}\right) * 100\%$	N/A	95%
B. Ready Utilization	Total time that unit can be used by operations group to perform productive work. This represents the capacity to do productive work not actual productive work.	$\left(\frac{\text{Ready Time}}{\text{Total Nominal (Calendar) Time} - (\text{Scheduled event} + \text{Unscheduled})}\right) * 100\%$	53%	85%
C. Drill Productivity	The number of production feet drilled per operational hour.	Ft Drilled / OH	137 Ft/ Hr	153 Ft/ Hr
D. Spatial Accuracy Percentage	The accuracy of hole placement, in the X, Y	Design Target x,y– Actual x,y in feet		95% +-12"

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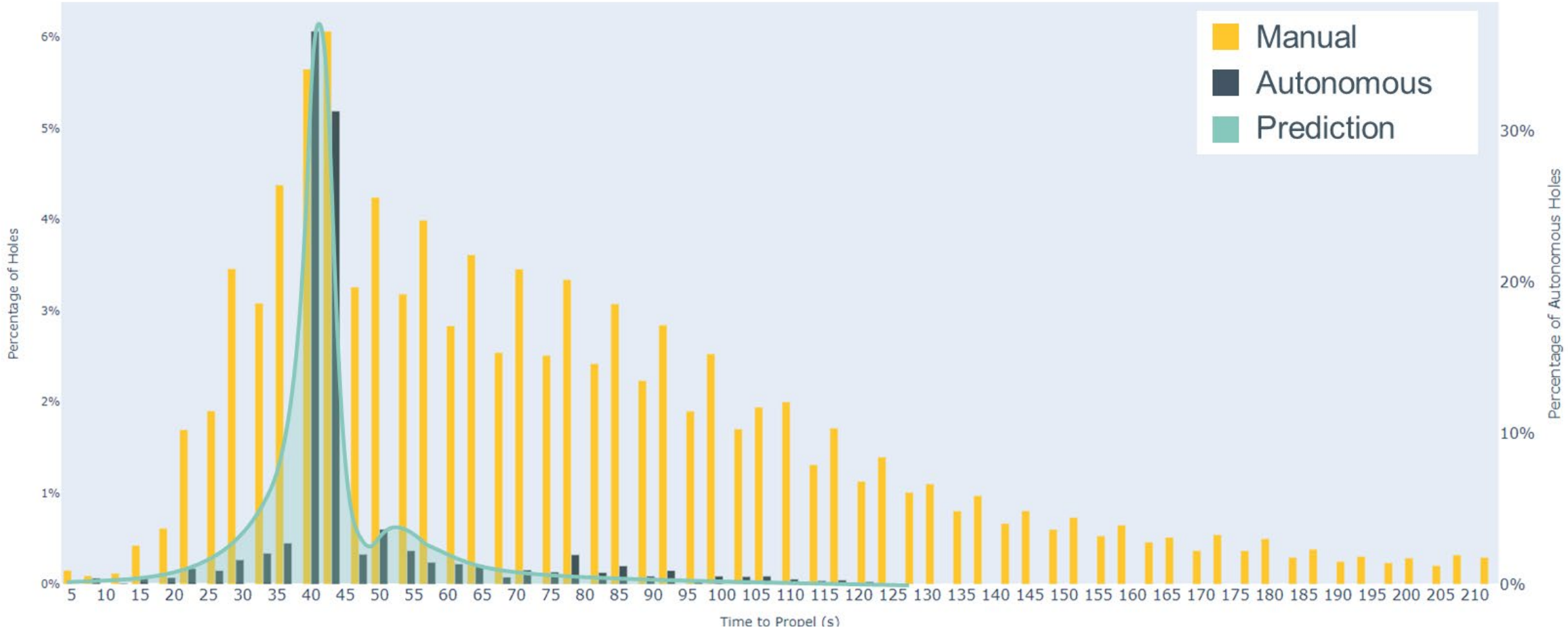
Drill Cycle Utilization

Actual Results

In Cycle – Propel Times



Predicted outcome is based on historical autonomous performance and machine capability; then slightly biased based on manual baseline (unknown conditions)

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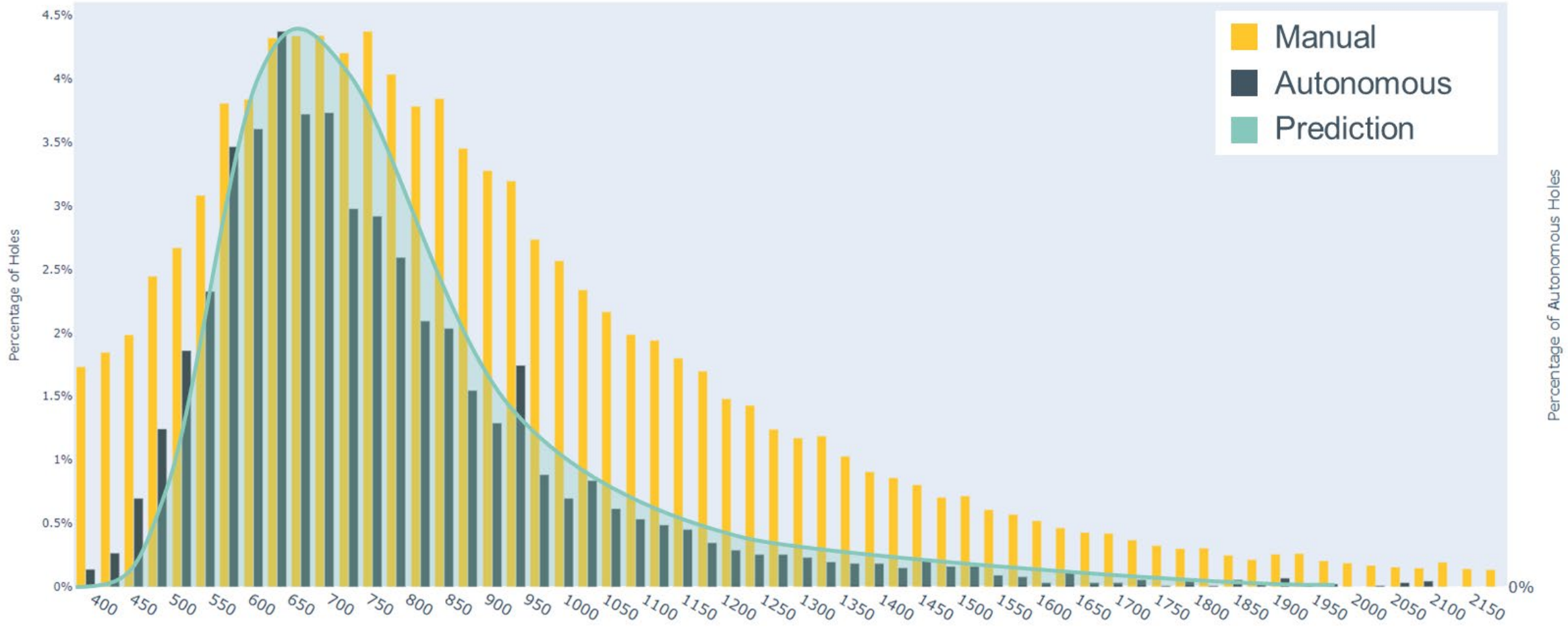
In Cycle – Drilling Times



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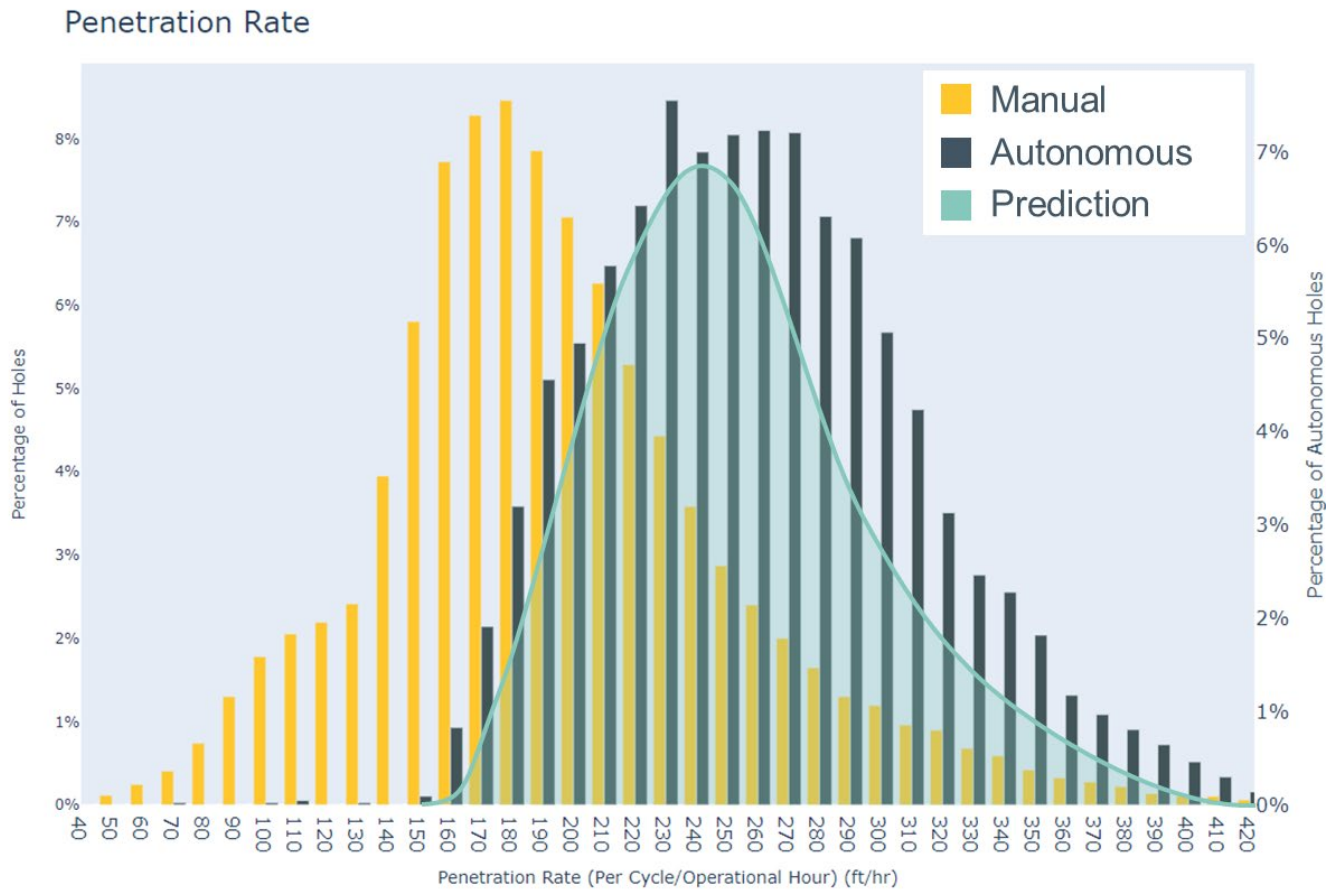
Drilling Performance

Actual Results

Penetration Rates

Per Operational Hour (ft/hr)



- **Definition:** Per Operational Hour penetration rate is defined as depth drilled over time spent in **productive** cycle time only (Tramming + Setup + Drilling).
- This can be used as a measure of full cycle effectiveness
- Assuming ‘productive’ time has been classified correctly, any difference between the distribution and that of instantaneous penetration rate is due to a lack of predictability or consistency in cycle times.

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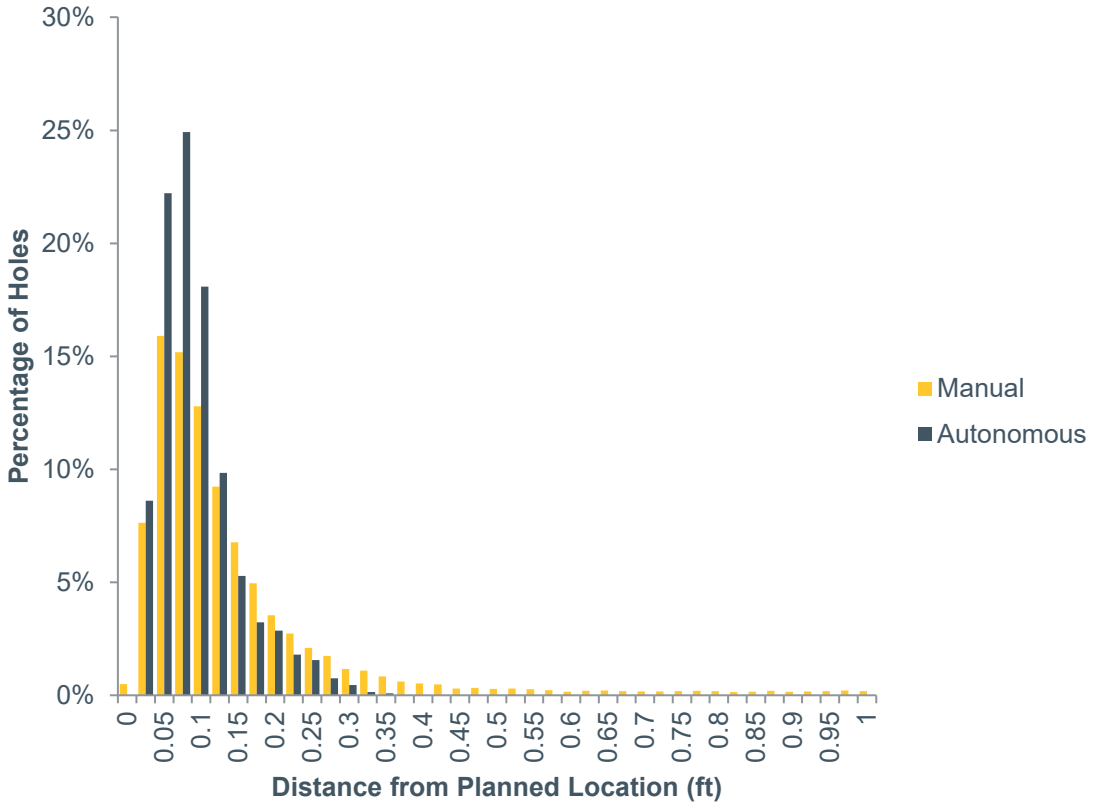
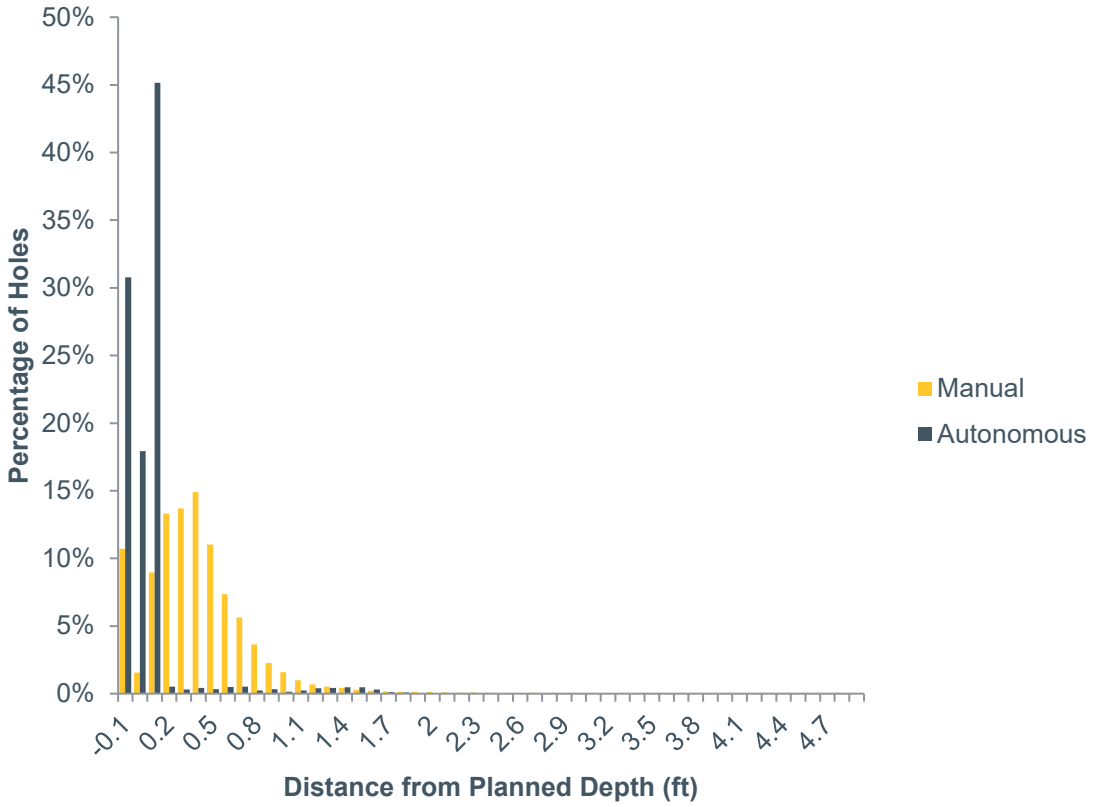
Hole Quality

Spatial Accuracy



Depth Accuracy



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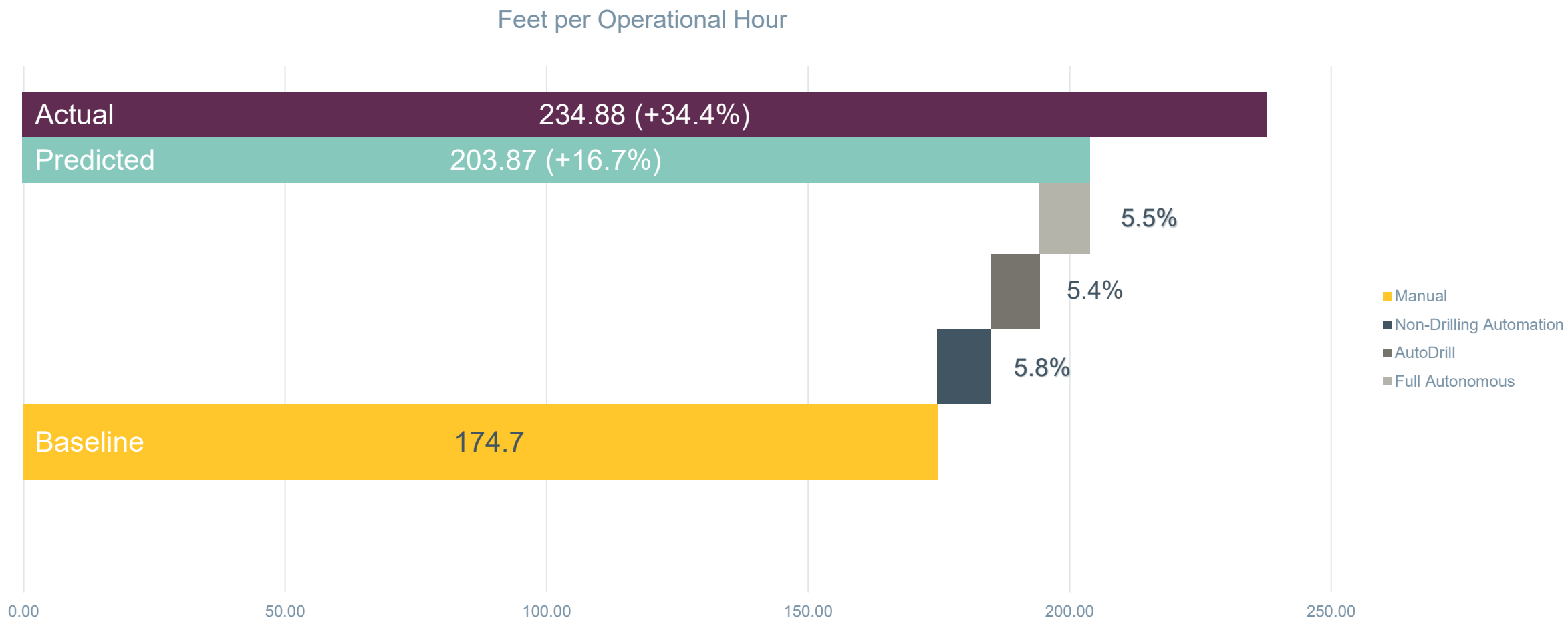
Autonomous Model

Prediction



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Robinson Mine

Project Success

- No safety incidents
  - Safer operations overall when operators are removed from the area
- Autonomous drilling has resulted in a productivity rate of 239.35 ft/hour
  - A 37% increase over the measured manual drilling rate of 174.7 ft/hour
  - Exceeded KPI of 203 ft/hour
- Production exceeded replaced PV351
  - Lower total cost of drilling
- Hole Quality Increased for Autonomous operation
  - Spatial accuracy >99%
  - Depth accuracy >99%
  - Exceeded KPI of 95%

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KGHM's Robinson Mine:

The first 100% Fully Autonomous drill site in the US

United. Inspired.

Performance unites us, innovation inspires us,
and commitment drives us to keep moving forward.
Count on Epiroc to deliver the solutions you need
to succeed today and the technology to lead tomorrow.

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