How Automation Deliver Value in Mining

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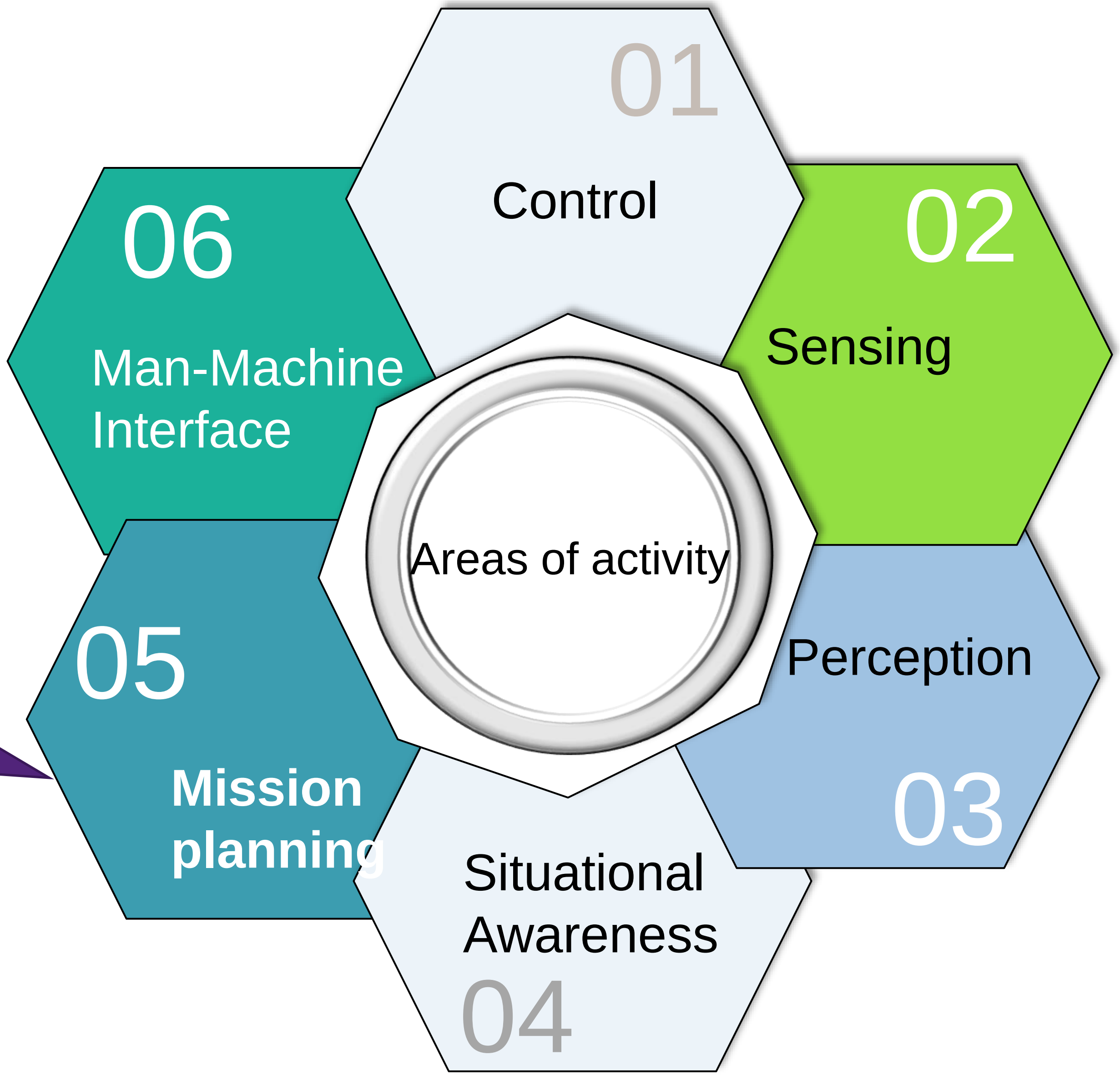
A big part of the answer is through precision

"By concentrating on precision, one arrives at technique, but by concentrating on technique one does not arrive at precision."

Bruno Walter, German pianist and composer

Automation components

Calm, carefully planned tactical actions that are faithfully and methodically executed with exactness and meticulousness.



We've been seeking precision through the solution of Bellman's equation?

Bellman's equation for a stochastic system:

$$V(S_t) = \max_{a_t \in \mathcal{A}} \{C(S_t, a_t) + \mathbb{E}[V(S_{t+1})]\}$$

S_t is the state of the system at timestep t.

$V(S_t)$ is the value of the state S_t.

$C(S_{t,} a_t)$ is the cost of making decision a_t from S_t.

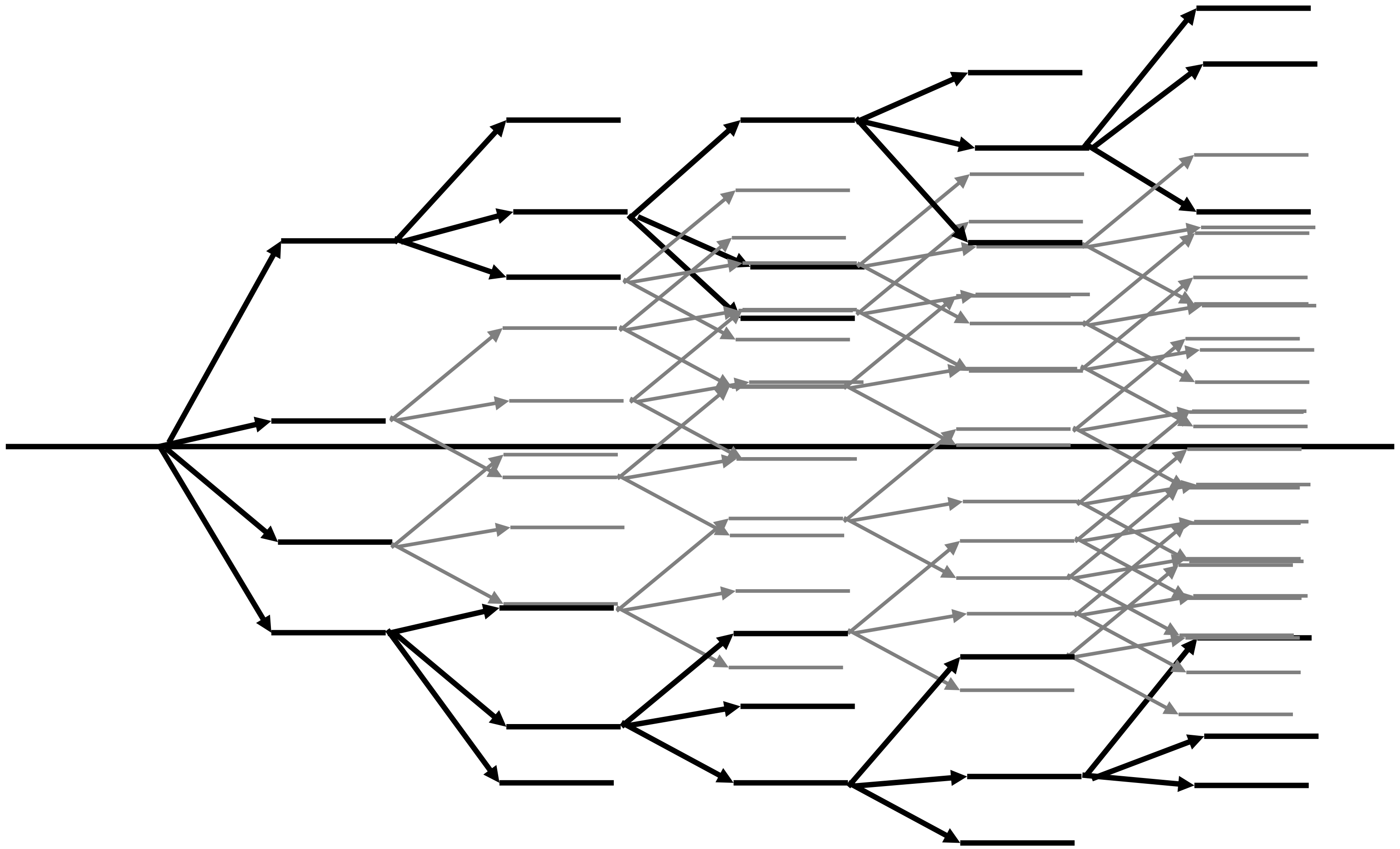
The state new state is given by the transition function S^M.

$$S_{t+1} = S^M(S_t, a_t)$$

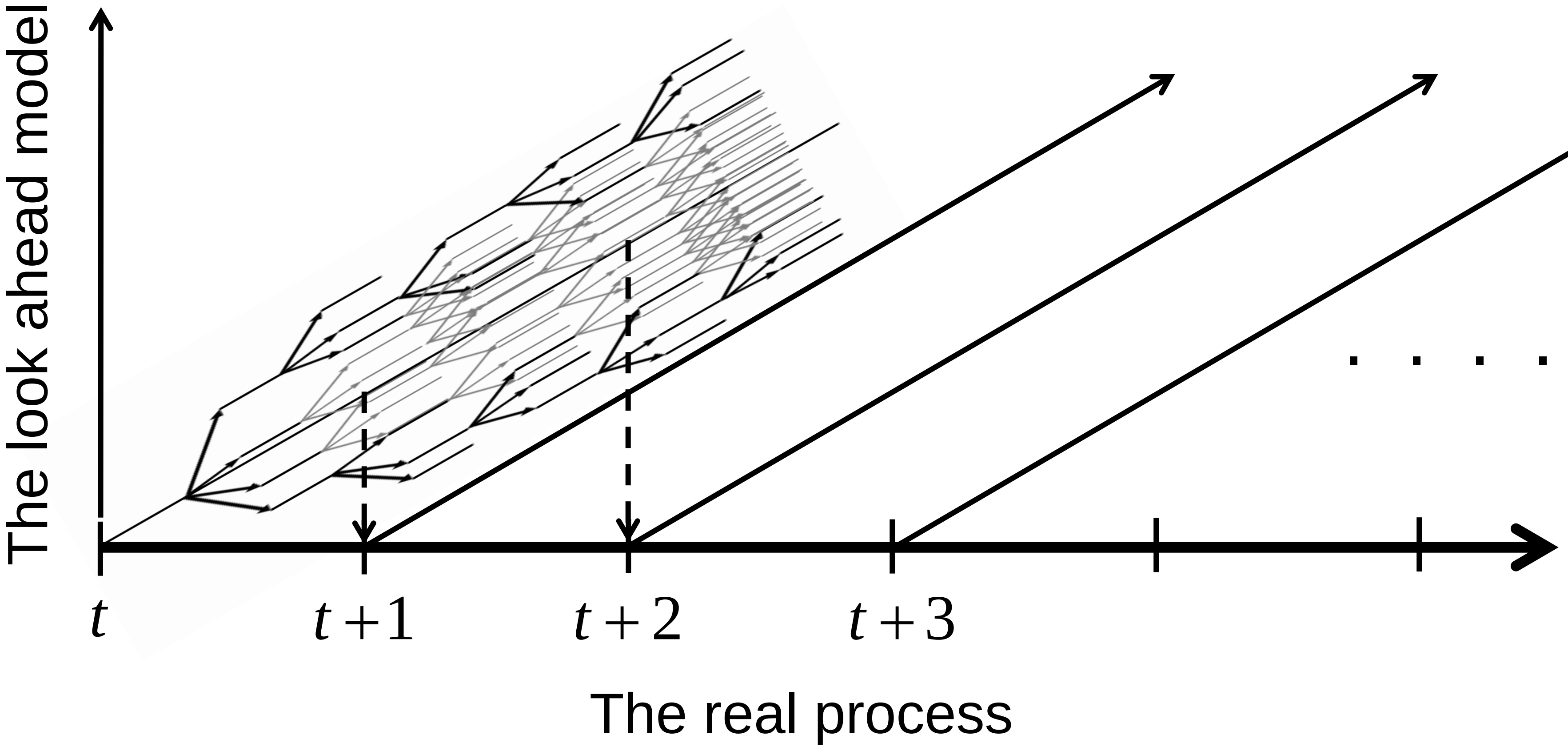
The optimal decision is given by:

$$a_t^* = \operatorname*{argmax}_{a_t \in \mathcal{A}} \{C(S_t, a_t) + \mathbb{E}[V(S_{t+1})]\}$$

Dimension is a curse so we need constraints and heuristics



Dimension is a curse so we plann on a receding horizon



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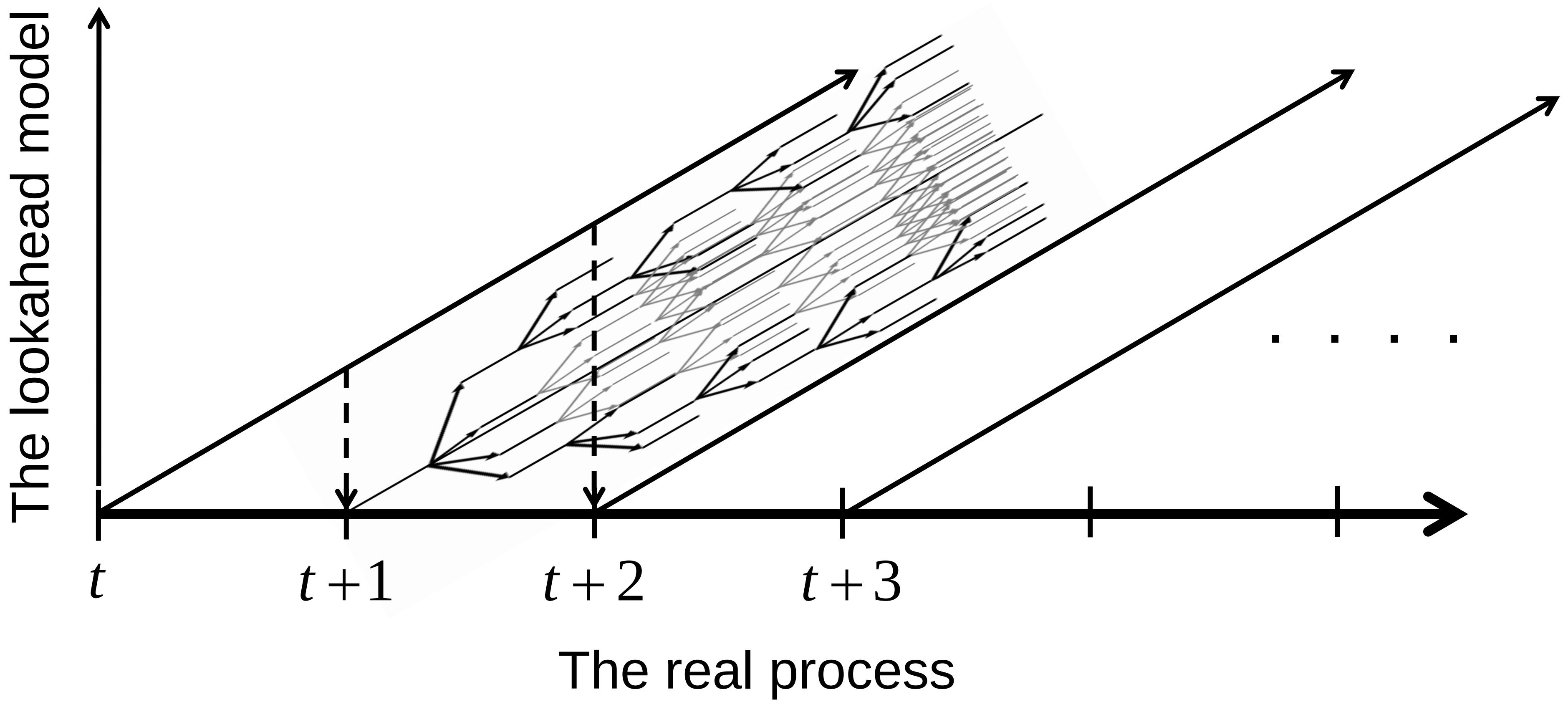
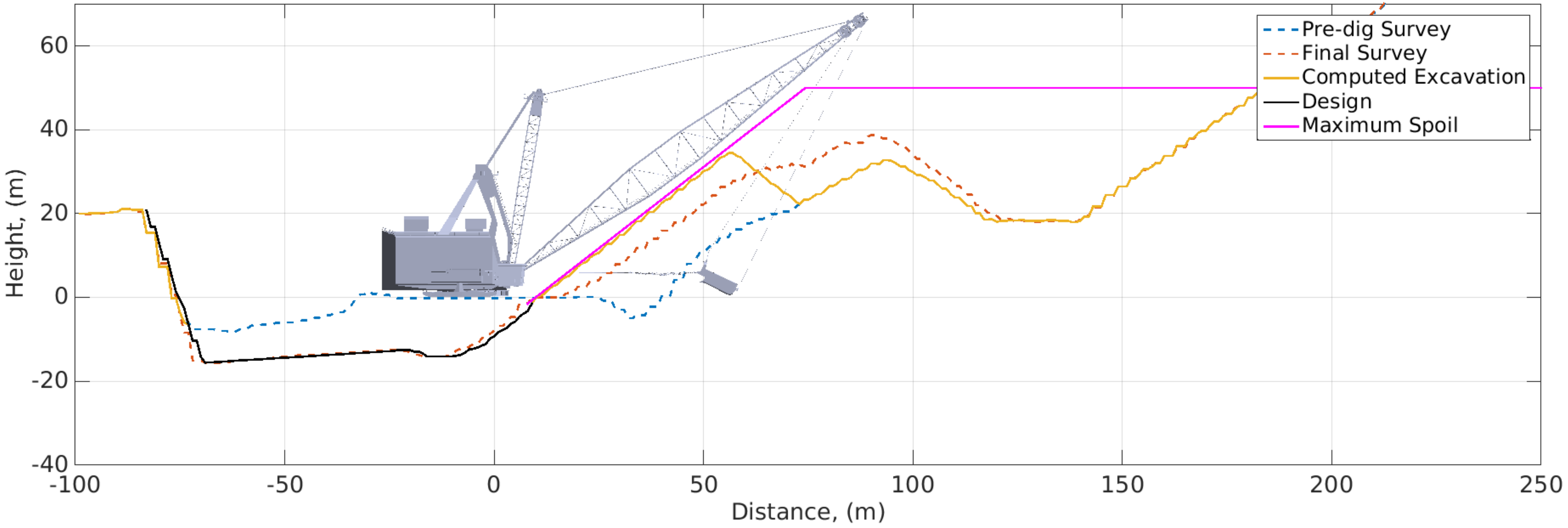
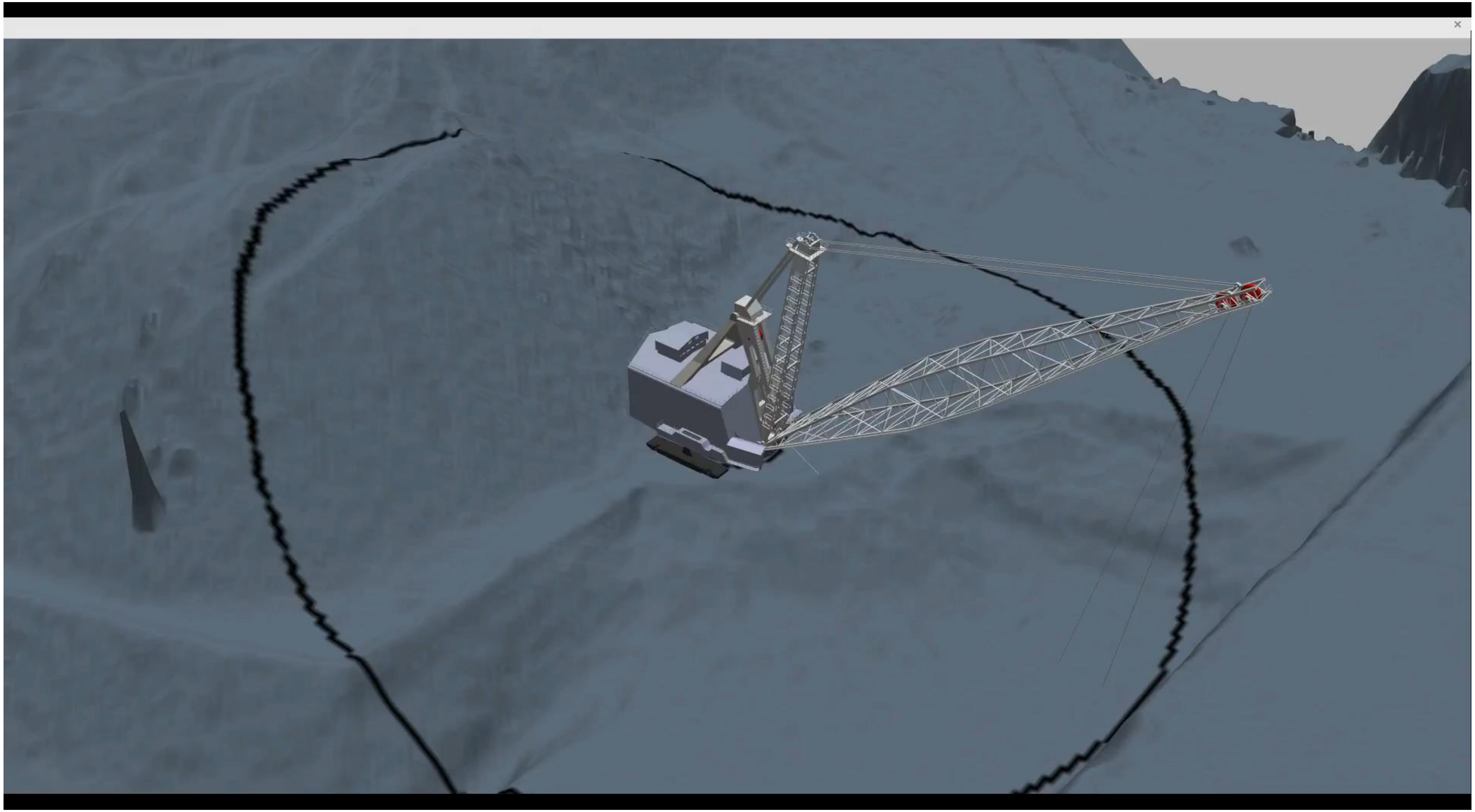


Dragline Excavation Sequencing

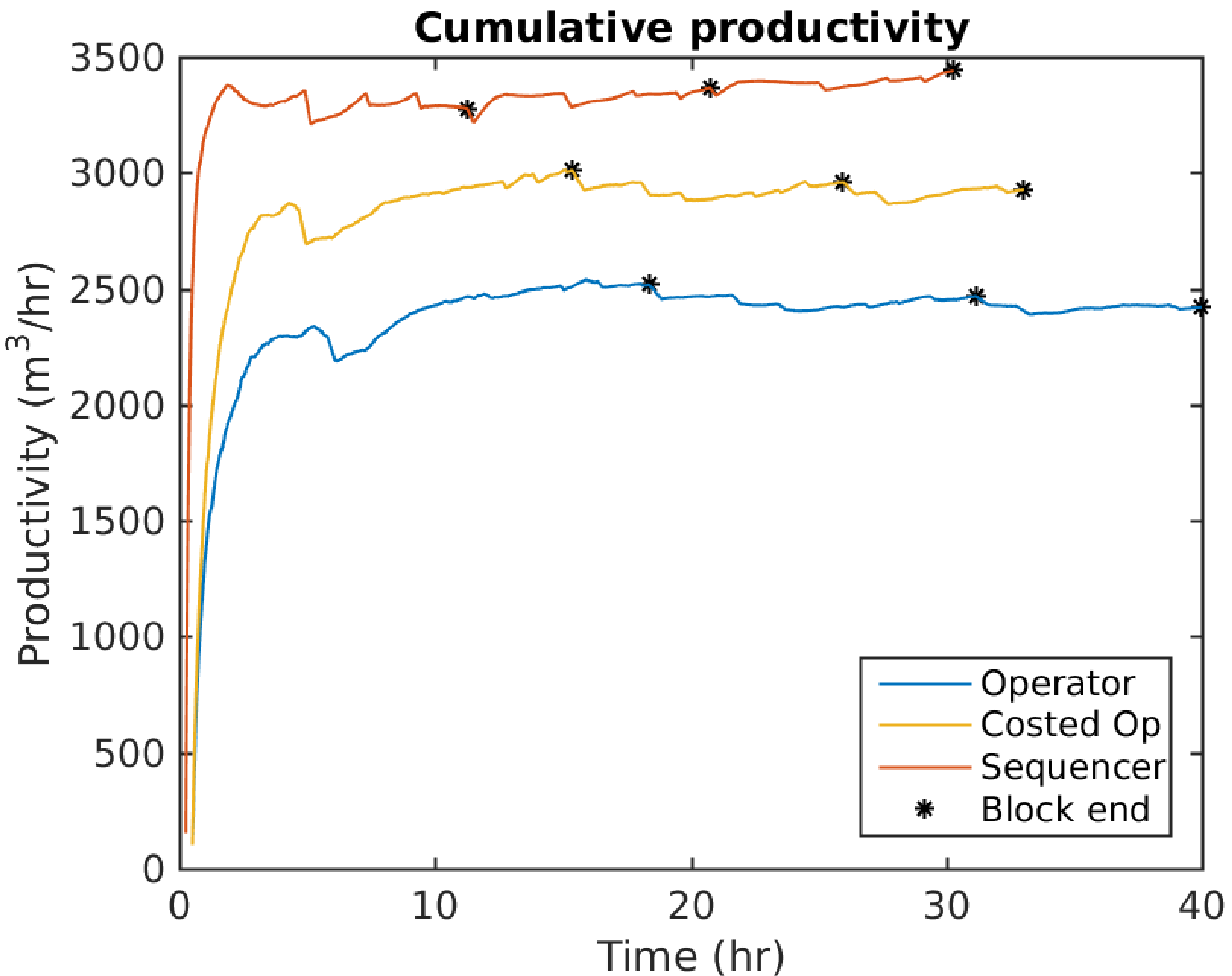
A 2D perspective to understand the problem



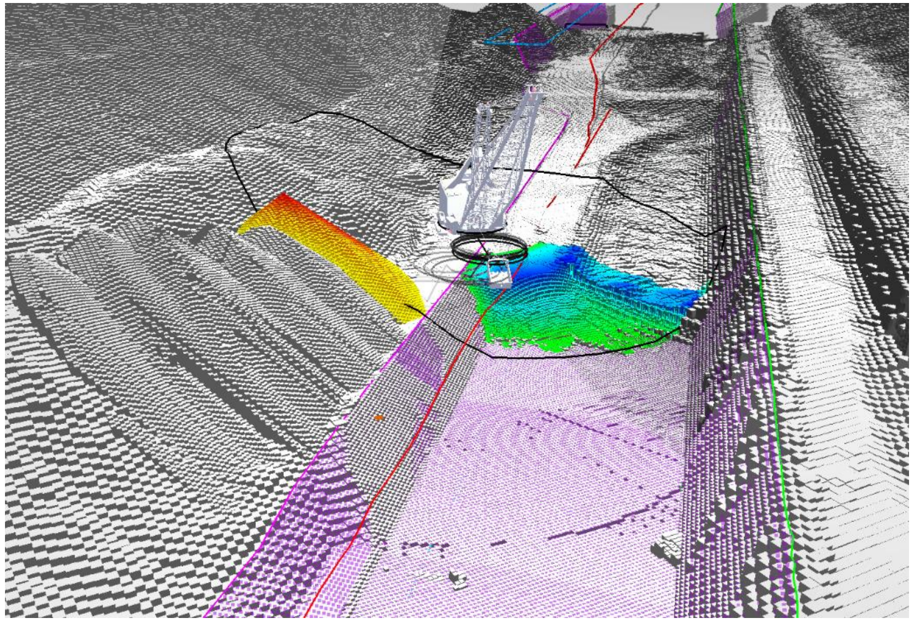
Excavation sequencing



Sequencer Performance – Productivity



What is the value?



Reduced swinging for same material movement

- **20% production improvement**:
- Realized through optimizing tub positioning and placement of spoil
- Enhanced situational awareness

Capability to fit the material – reduced rehandle

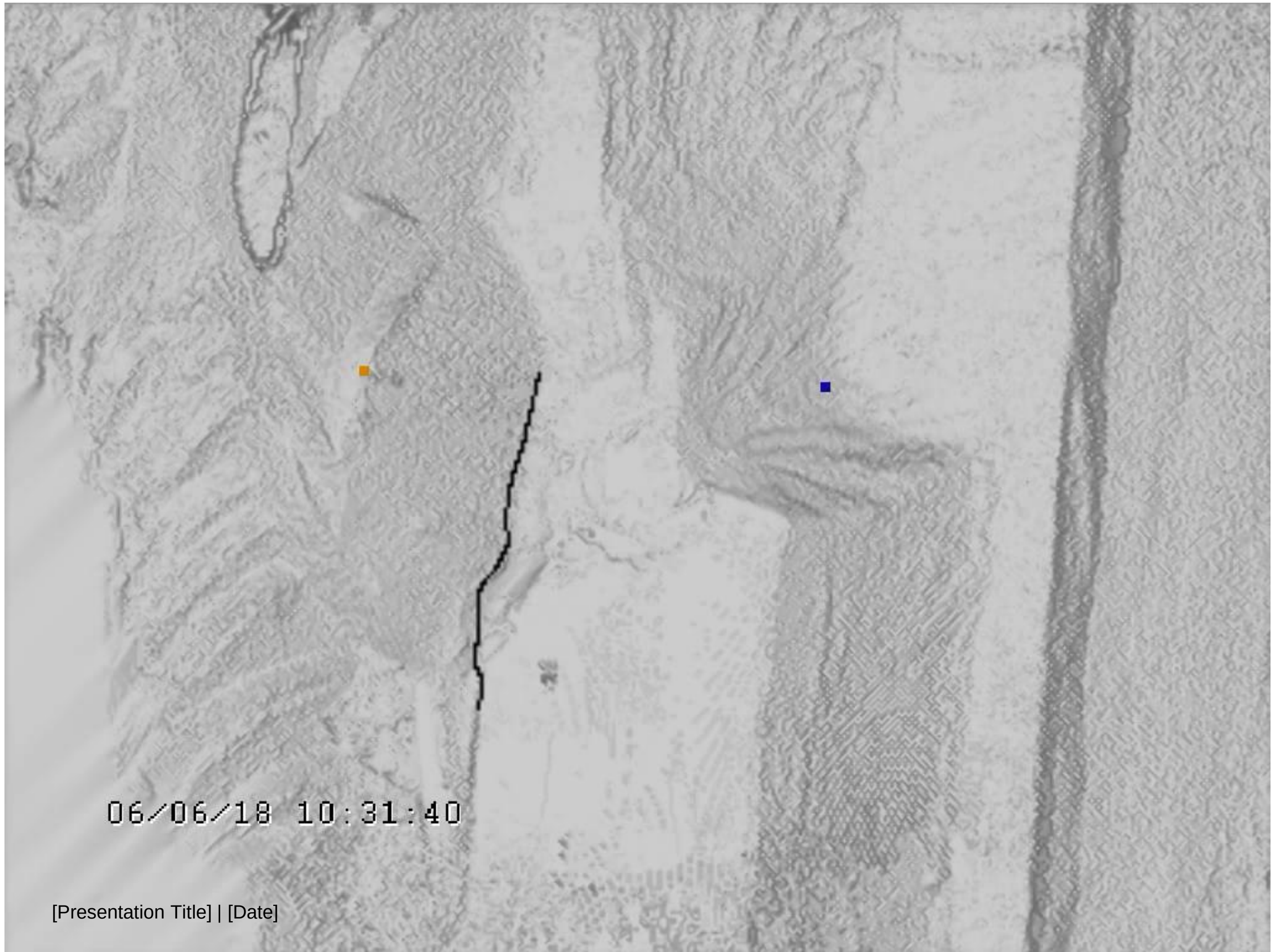
Driving the machine at its limits

- Will require automation to realize.
- **Up to 25% gain in productivity**

Automating the machine

- Excavation sequencing capability required.

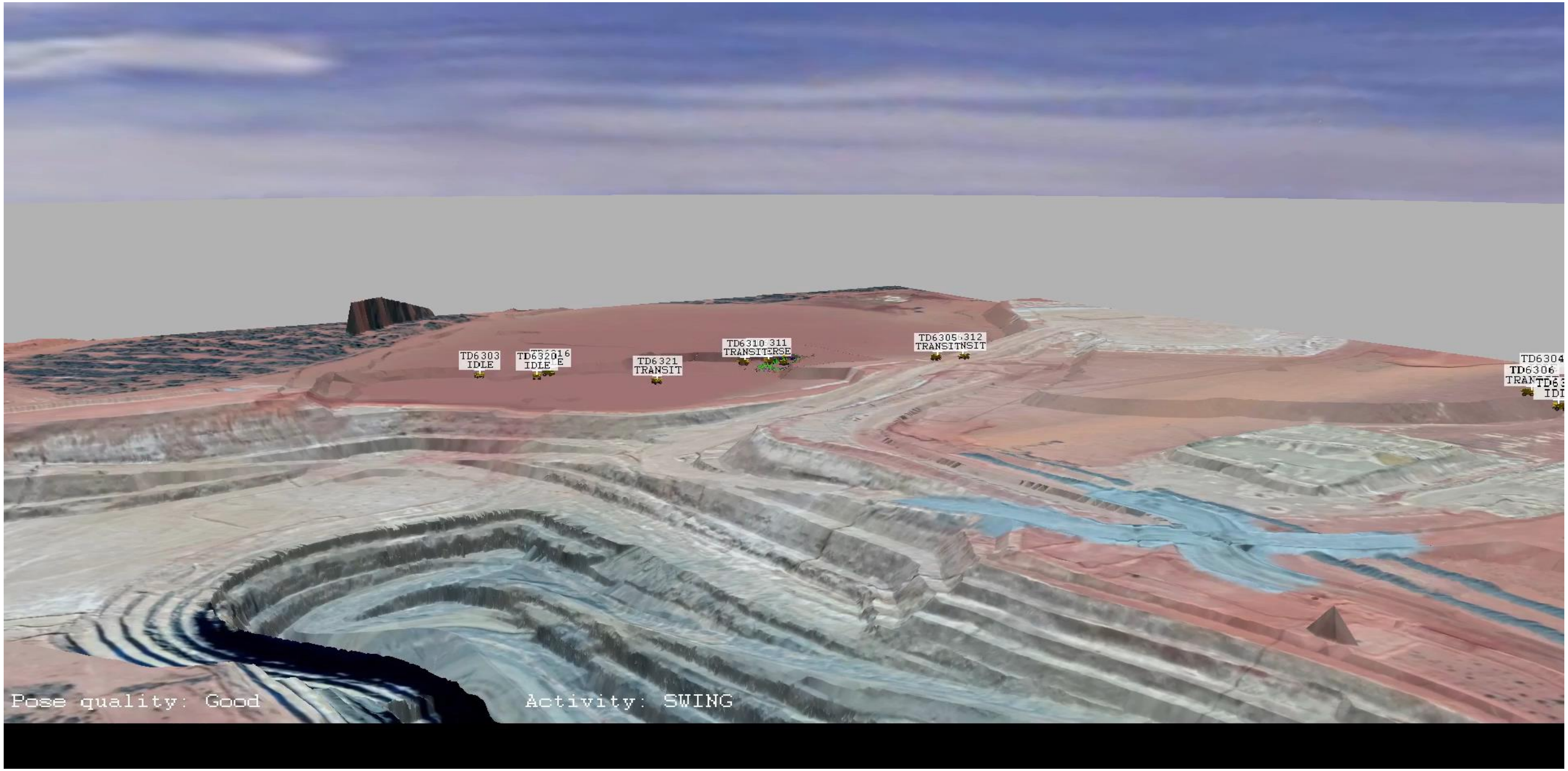
Can we extract latent value by providing the operator with guidance encouraging greater precision?



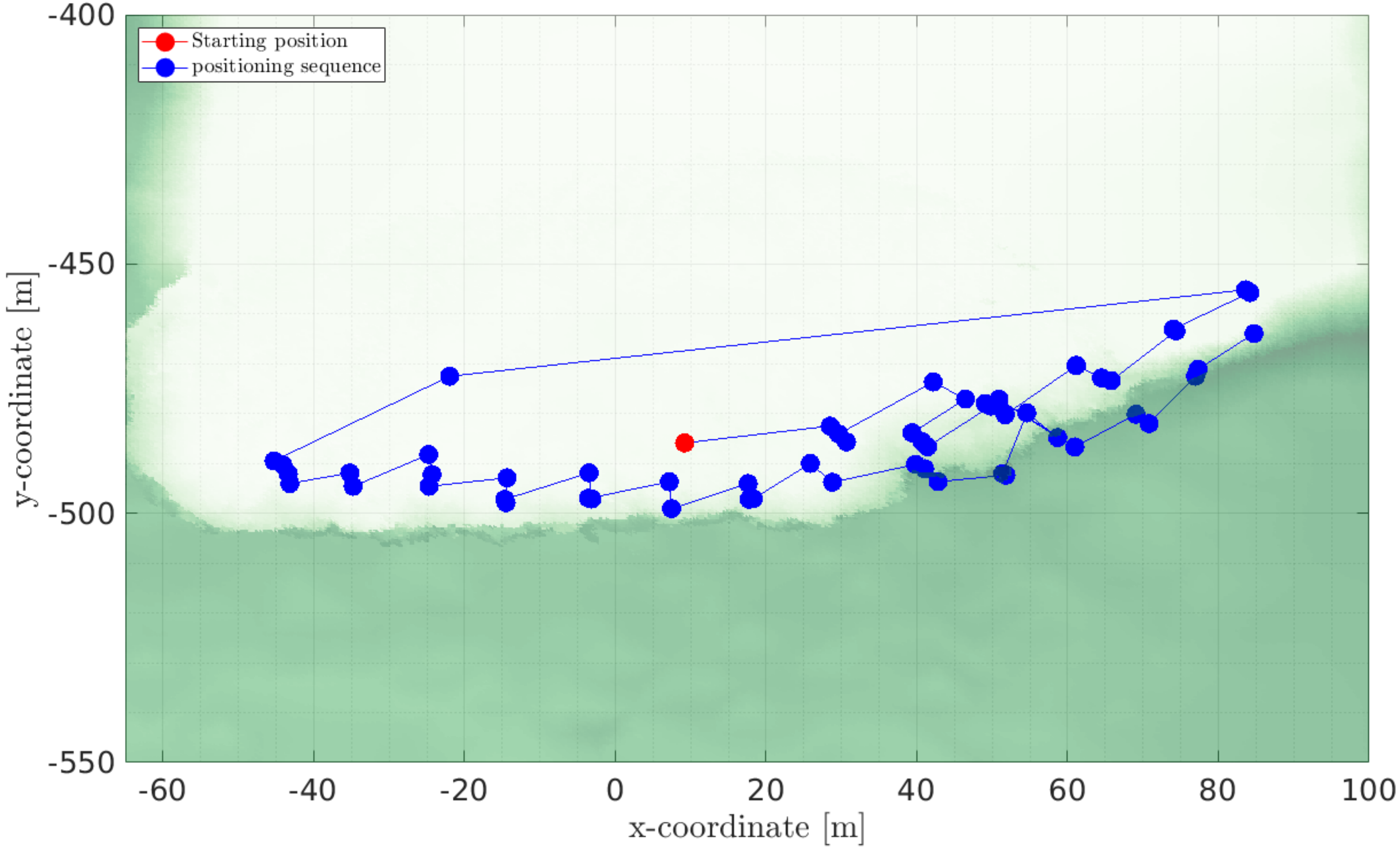
What about hydraulic excavators

1. Benchmark 6060 excavator performance by conducting a trial to quantify productivity.
2. Determine how to 'optimally' sequence an excavation by considering the triple question of where to dig, where to move and when to move.
3. Establish the benefit of optimally sequencing the excavation by comparison to the benchmark.

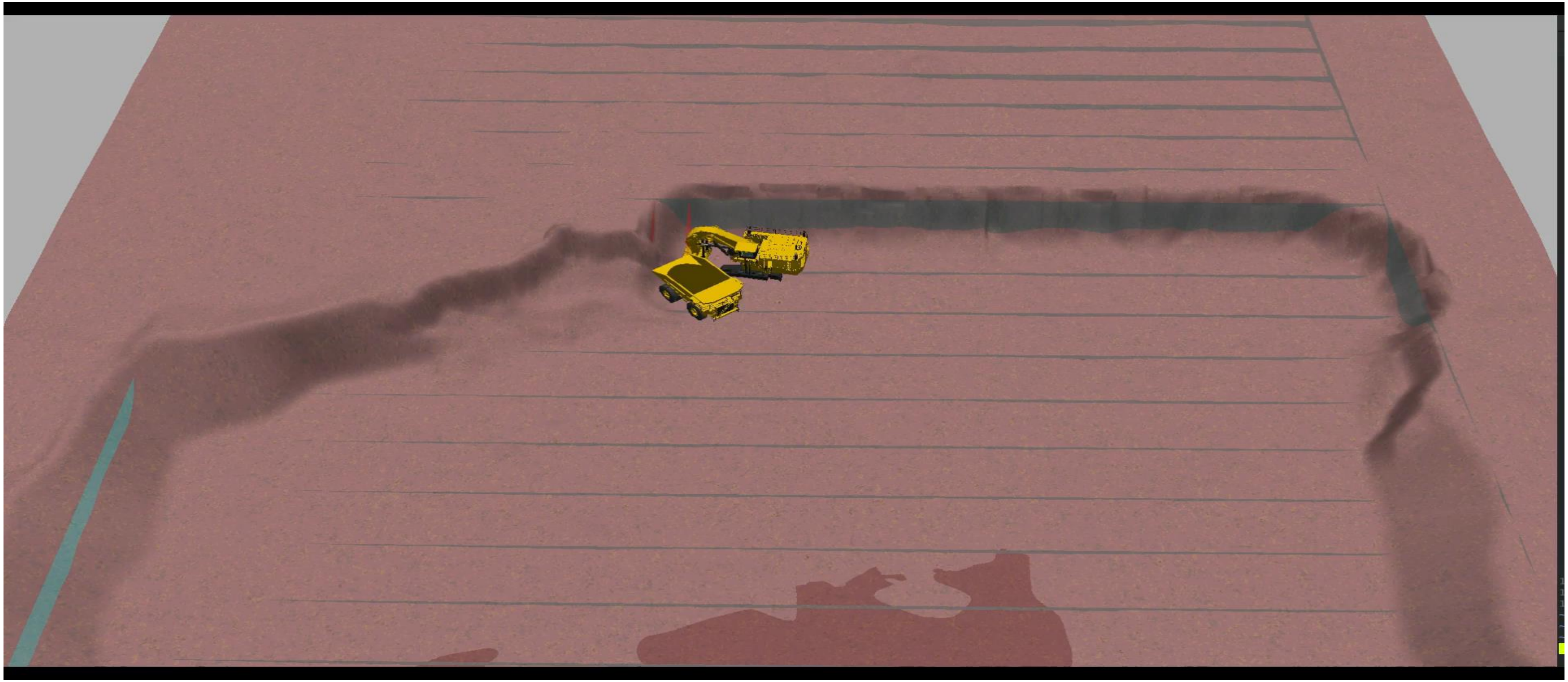
Benchmarking the shovel productivity



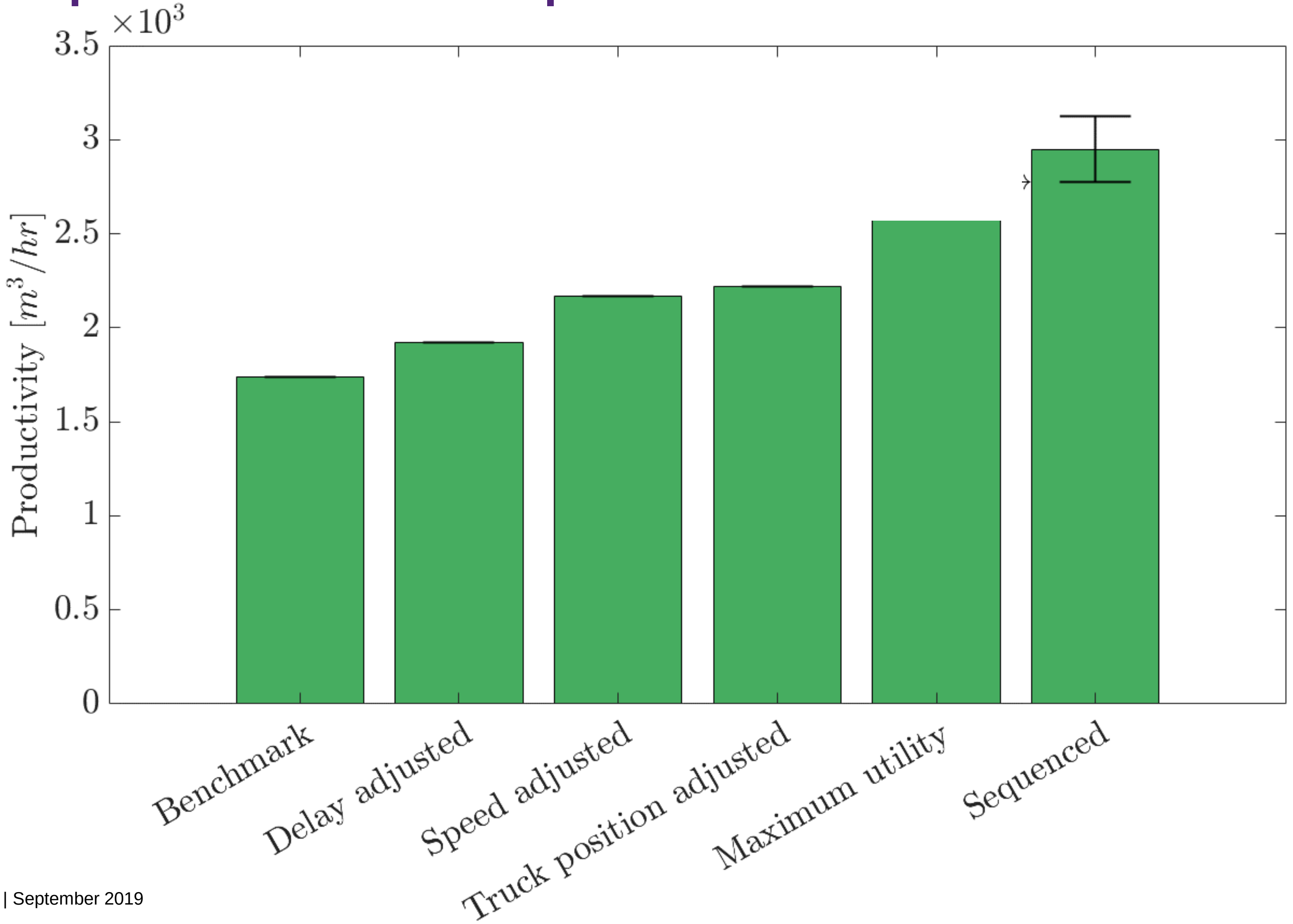
Operator Excavation sequence



Shovel excavation sequencing



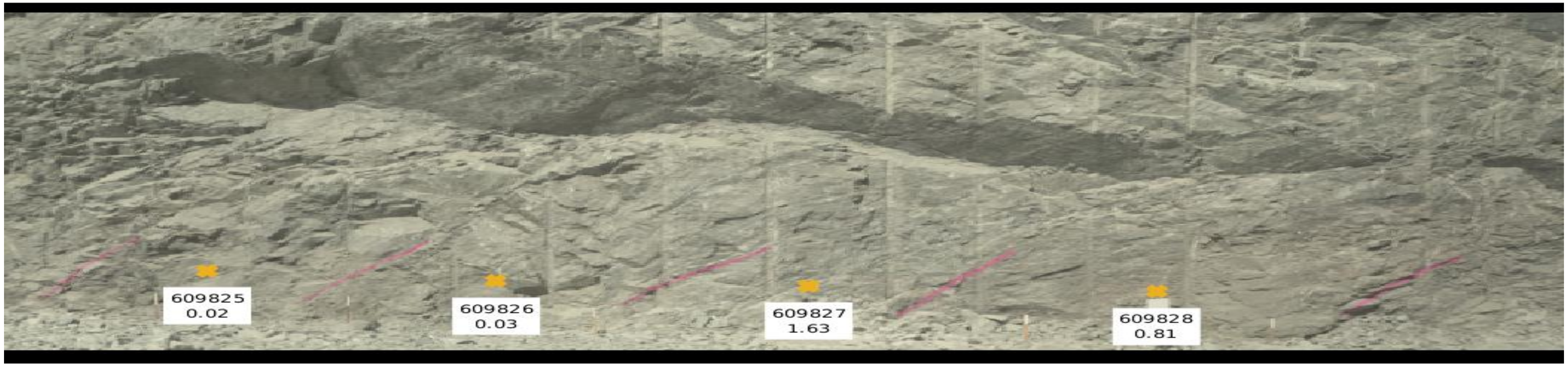
Comparison of the productivities



Precision ore mapping (with PlotLogic)

A gap exists in real-time ore body knowledge for autonomous mining systems.

Site 02



Field-deployed equipment

Head unit consisting of:

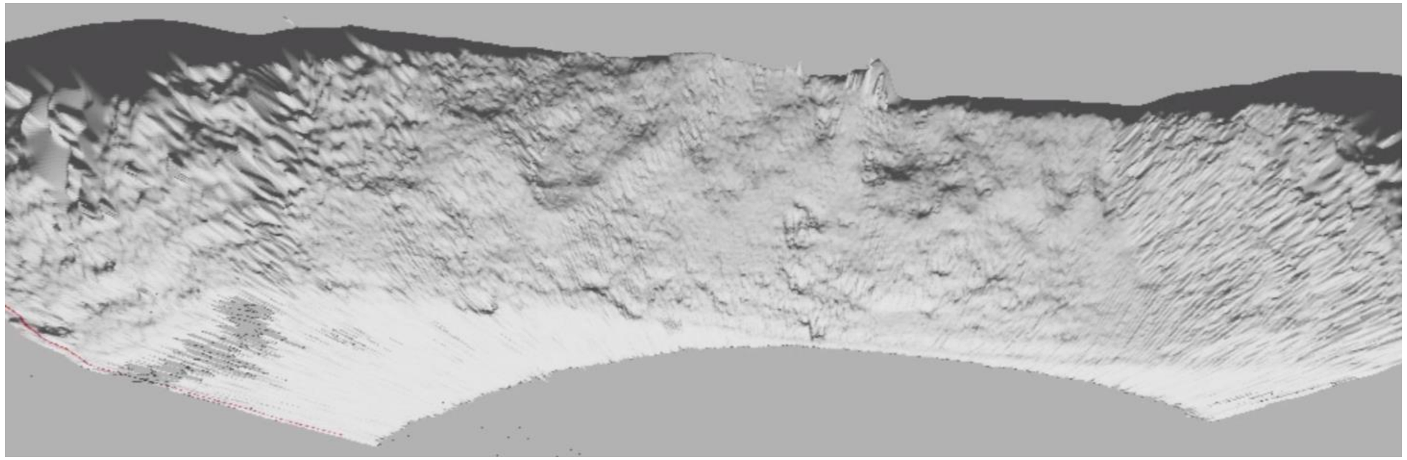
- LiDAR for terrain mapping
- Visible and near infrared (VNIR) hyperspectral camera (400-1000nm)
- Short wave infrared (SWIR) hyperspectral camera (950-2500nm)

Mounted on a rotating platform (pan and tilt) for capturing entire dig faces.

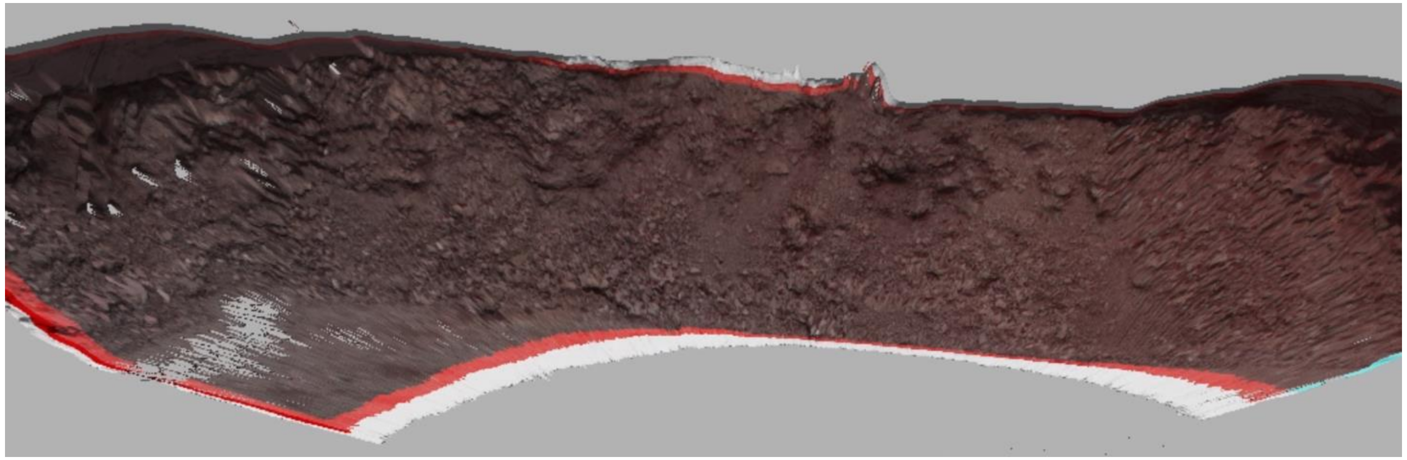
GPS for geo-referencing the survey.

System workflow

1. Map terrain with lidar-only sweep.
2. Capture and fuse hyperspectral data to produce 400-channel datacube mapped to terrain.
3. Real-time classification with pre-trained classifier.



Visualization of generated terrain



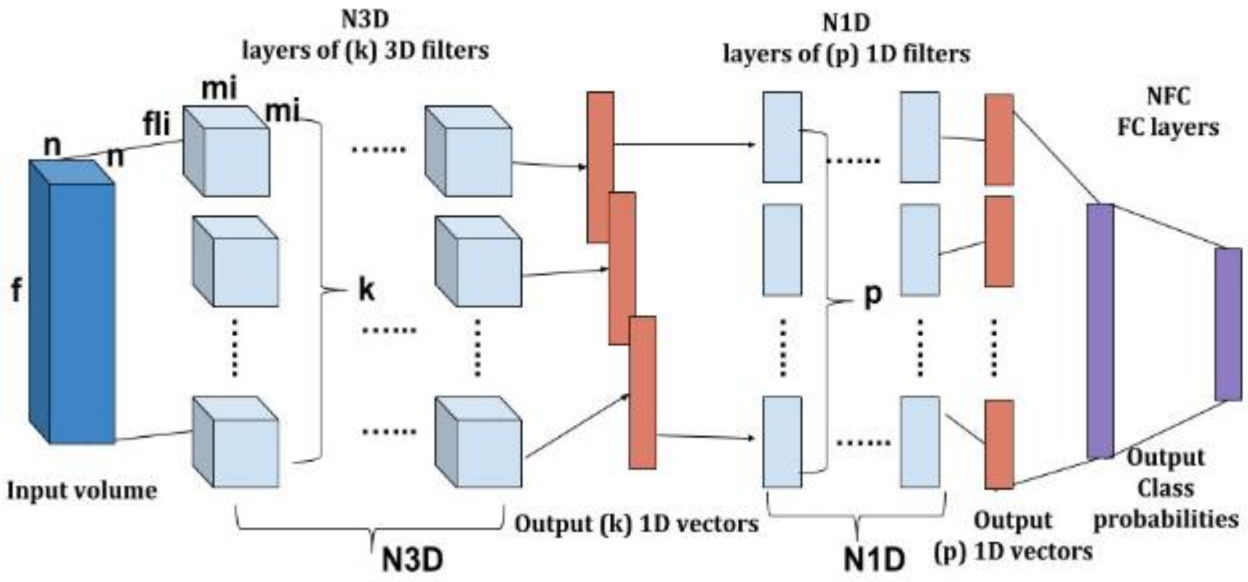
False-colour RGB image of fused hyperspectral images

Convolutional neural networks for classification

Machine learning is the state of the art for hyperspectral classification problems, with significant research interest and success in convolutional neural networks (CNNs).

A common approach is to convolve small filters across the full spectral dimension and a small spatial region, to output a classification for each pixel in an image.

Common CNN architecture demonstrating layers of 3D and 1D filters convolved over the input spectral patch, followed by fully connected layers.

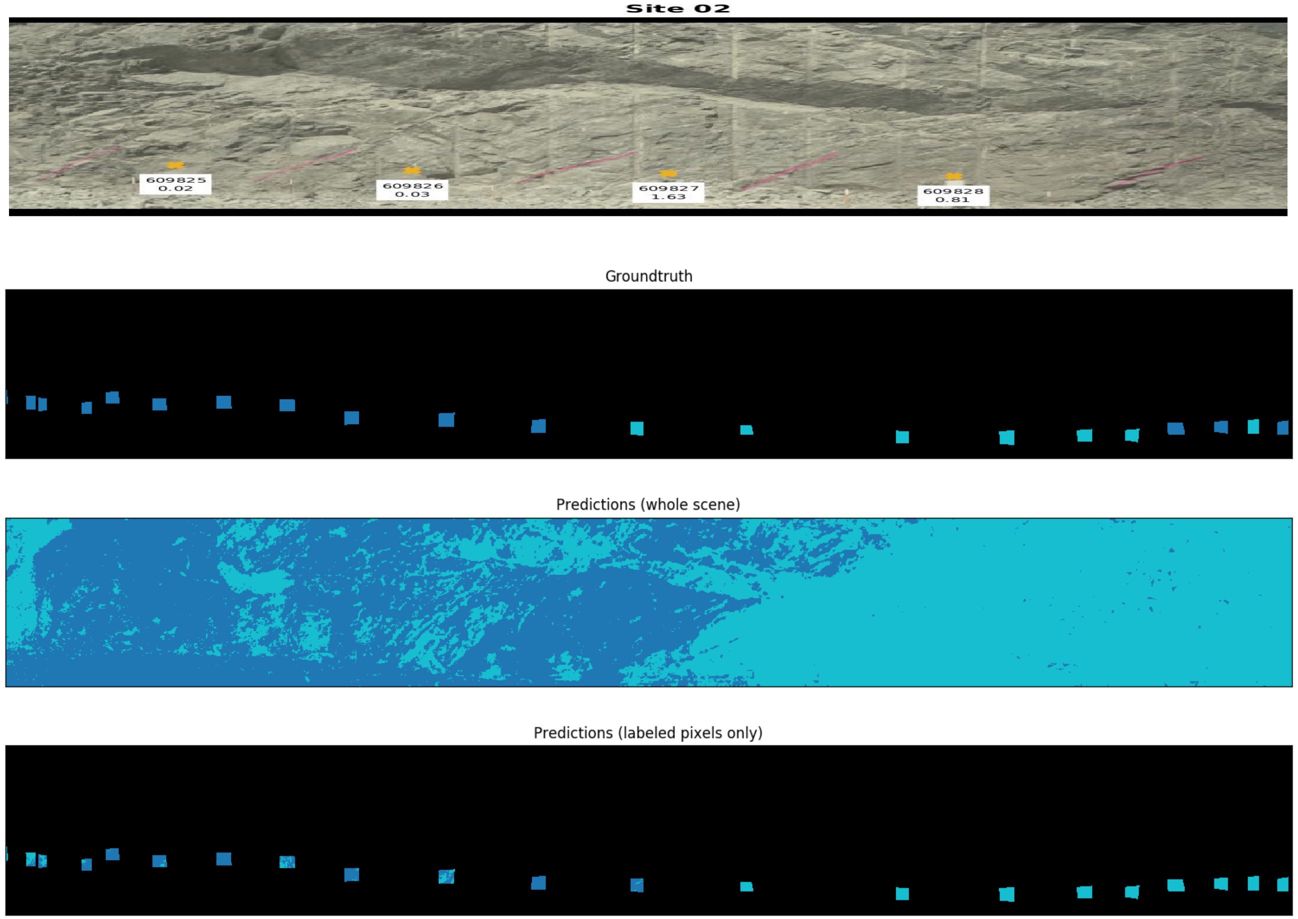


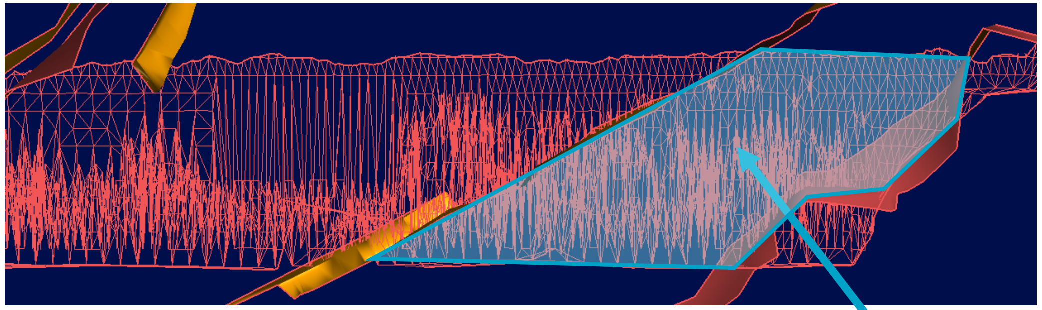
3-D Deep Learning Approach for Remote Sensing Image Classification
Amina Ben Hamida, Alexandre Benoit, Patrick Lambert, Chokri Ben Amart
IEEE TGRS, 2018
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8344565

Field survey classification performance

Our strongest result to date is to show that hyperspectral imaging can be used to distinguish ore from waste.

Can we establish mineralization?





Geological model of scanned scene

Region of gold mineralisation

>0.5 ppm

<0.5 ppm

Conclusions

- The main thrust of this talk is linked to my strongly held view that to increase production we should have focus on precision in mining in its broadest sense.
- At UQ we have conducted a number of related studies and worked on aligned technologies – some of which I have described today – which suggest there is a significant opportunity in more precise activity around excavation
- Much of this opportunity appears to be related to capturing ‘operator losses’, arguing the case for automation to support or replace operators.