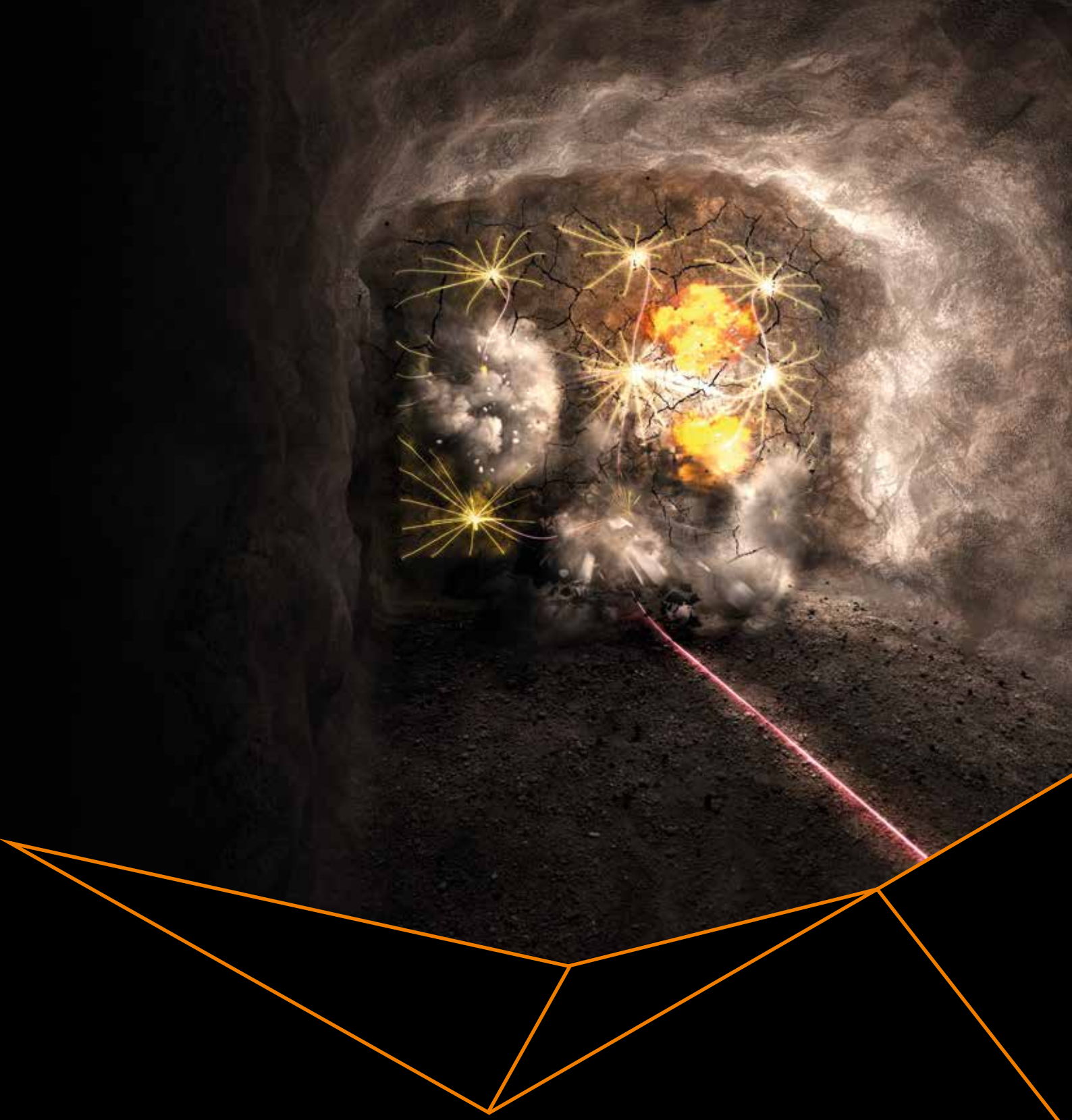


iSURE™ SOFTWARE
DRILL AND BLAST INTELLIGENCE

SANDVIK

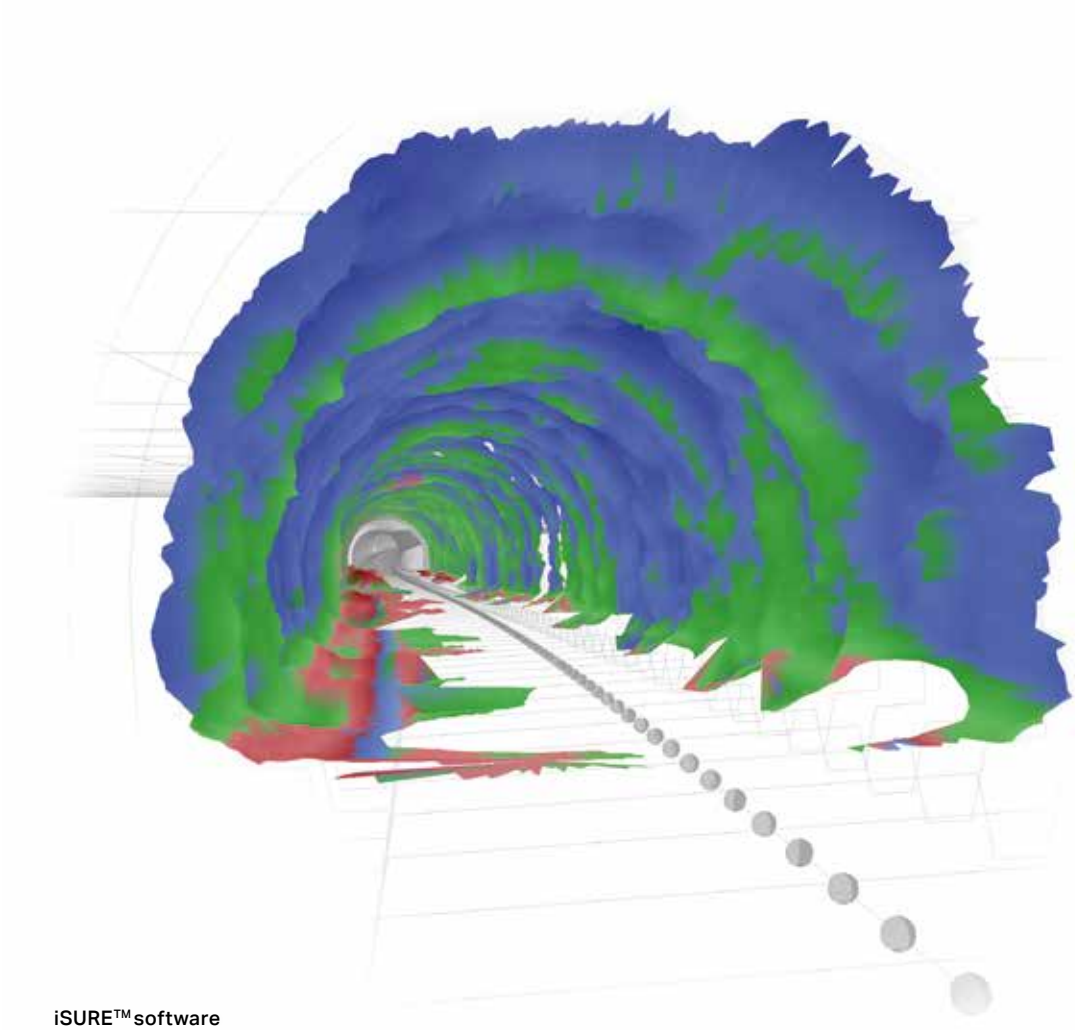
THE ART OF DRILL PLAN DESIGN

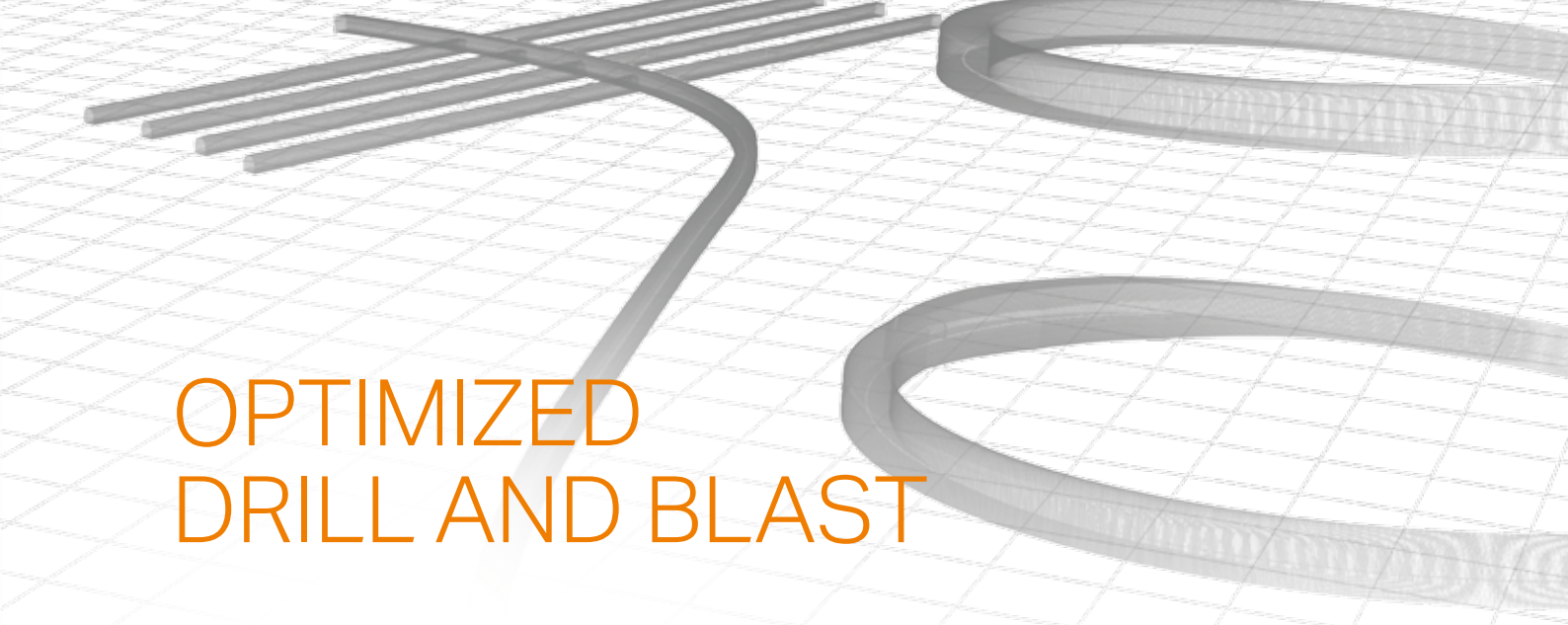
The key points of successful tunneling are quality, cost, schedule and safety. To achieve the best results, accurate drilling and blasting together with professional design and professional people are required. And wherever accurate drilling, blasting and design are needed, iSURE™ software and iSERIES drilling rigs make all the difference.

iSURE™ software (Intelligent Sandvik Underground Rock Excavation software) is a computer program for Tunneling Construction and Mining drill and blast process control. It produces all the data you need for an optimized drilling and blasting cycle.

The full-featured iSURE™ software utilizes your drill rig's data collection to improve the work cycle and the drill and blast excavation process. It also has an optional toolset for geological analysis (iSURE™ GEO), a tunnel profile 3D scanning system (iSURE™ 3D SCAN) and an interface to a third party blasting vibration feedback system.

iSURE™ software capitalizes the improved accuracy of iSeries rigs for drill and blast usage.





OPTIMIZED DRILL AND BLAST

Drill and blast optimization means taking into consideration the changes in rock blastability and other changes in the environment. iSURE™ software offers a rich set of plan editing and feedback functions to achieve the best possible result out of the blast.

Optimization can mean different things in different cases: Good excavated profile quality means savings in scaling and shotcrete. On the other hand, a profile within tolerances translates into avoiding extra costs for concrete lining or waste rock loading and hauling. Moreover, underbreak correction interferes with the normal work schedule and needs to be avoided.

A controlled blast results in good pull out, restricted fracture zone and greater rock strength around the tunnel. Round's length can be tuned to allowed vibration level and geology. Getting a predicted drill and blast cycle time is not a minor thing to a success story of the project.

Drill and blast design is one of the cornerstones of iSURE™ software.

THE MAIN TARGETS FOR iSURE™ SOFTWARE DRILL AND BLAST DESIGN DEVELOPMENT:

- ✔ The 3rd plan in a new jobsite to function significantly well. It is not economical to excavate half of the tunnel to find out how it should have been done from the very beginning.
- ✔ The design principles of a good and working plan can be transferred into another. Values found in certain rock conditions will work well also with substantially different tunnel profiles.
- ✔ The drill plan can easily be divided into different blasting categories (bottom, roof, walls, free face) in Contour, Aid rows and Field as they are different to blast.
- ✔ Editing of a plan can be finished in 15 minutes.
- ✔ All the information will be inbuilt into the plan for easy bypassing.
- ✔ The program produces all the reports that are required for official acceptance.
- ✔ The program produces all the necessary information for charging work.

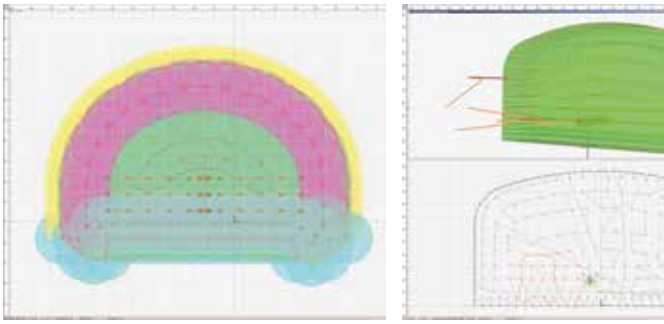
DATA DRIVEN PRODUCTIVITY

DEFINE THE TUNNEL

TUNNEL LINE AND THEORETICAL PROFILE DESIGN

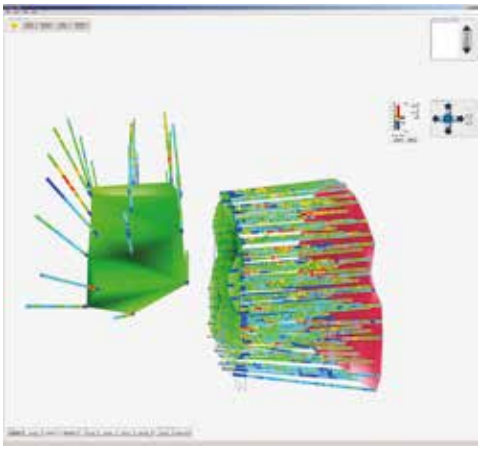
OPTIMIZE DRILL AND BLAST

DRILL AND BLAST DESIGN AND SIMULATION



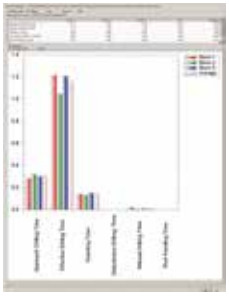
COLLECT AND MONITOR DATA ONLINE

ONLINE MWD

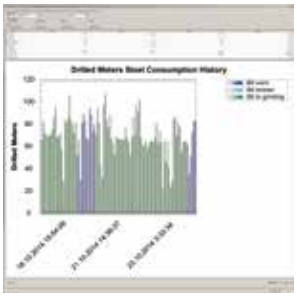


ANALYZE DATA, CONTINUOUSLY IMPROVE

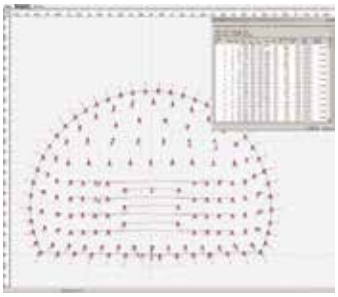
RIG EFFICIENCY



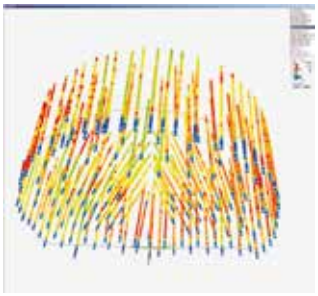
DRILL STEEL CONSUMPTION



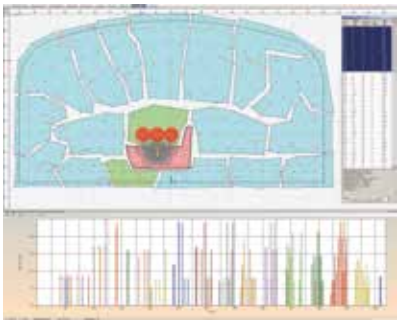
AS DRILLED



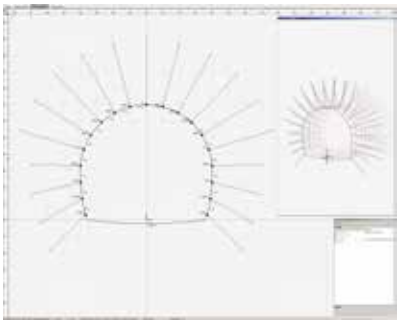
3D SHAPE AND MWD



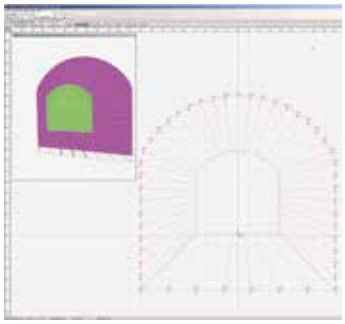
DESIGN SUPPORT

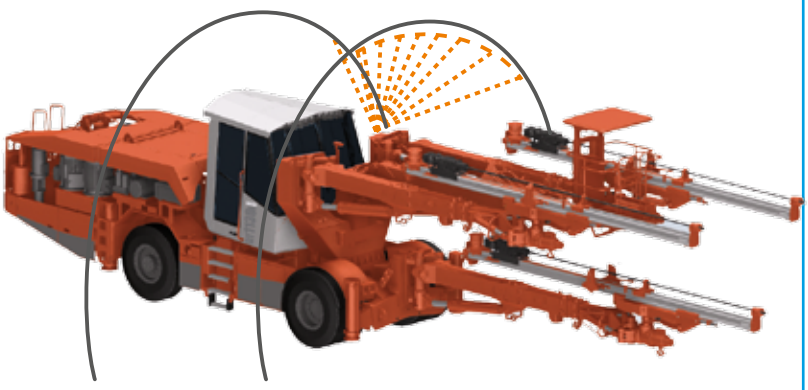


BOLTING DESIGN



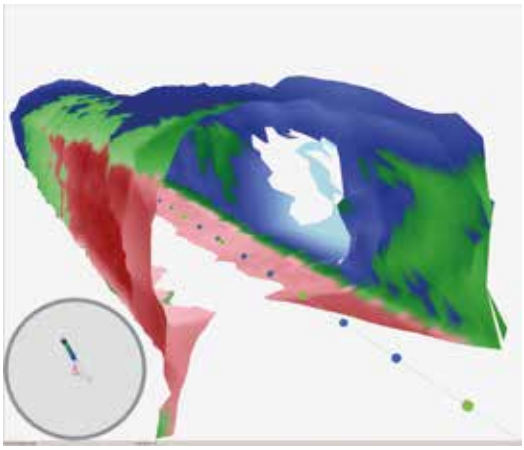
INJECTION PLAN DESIGN



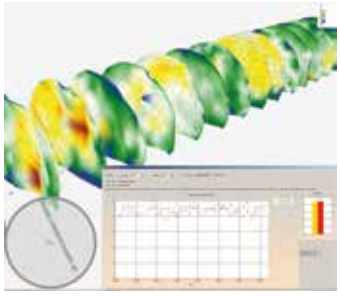


VERIFY

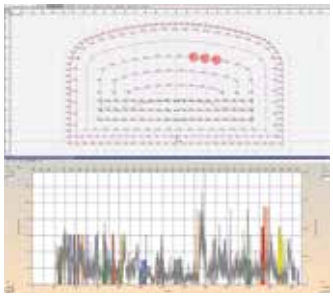
3D SCAN



PULL-OUT

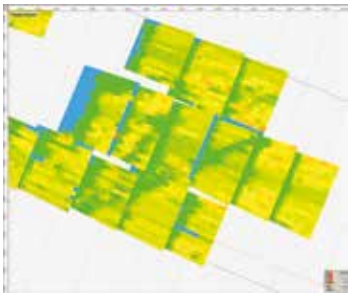


BLAST VIBRATION



ANALYTICS

GEO



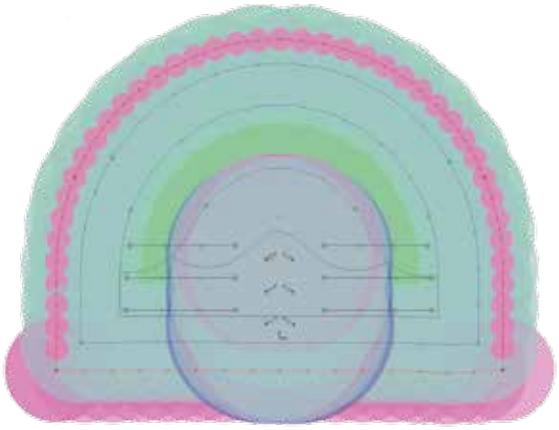
OPTIMIZATION FROM THE BOTTOM OF A ROUND

Round's blasting is most challenging at the bottom of the round. That's why the iSURE™ software patented design logic locates the endpoints of the holes first. Hole spacing, burden and specific charge values [kg/m^3] are calculated at this blast plane. More freedom can be allowed for the direction of the holes.

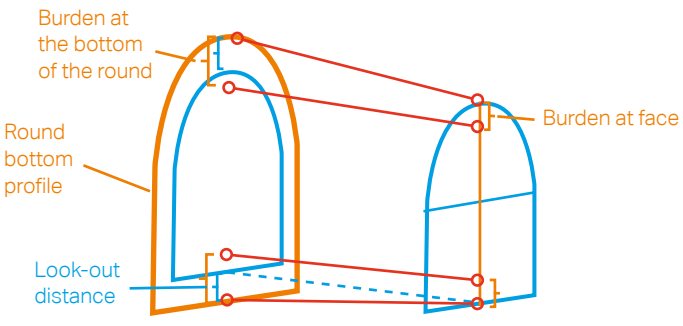
The patented design process starts by pointing out master holes at contour in the blast plane. Master holes divide the profile to different blasting categories – like roof, wall, floor – as they are different to blast. Fracture (EDZ) zone is visualized in order to not use too heavy explosives. iSURE™ software calculates the burden inwards, which will be the distance the contour holes can still break the rock. When parameters are right, this will be the place to locate the previous row of holes in detonation order e.g. Aidrow 1.

More powerful explosives can be used in this Aidrow 1 as holes are located further away from the remaining tunnel wall. Master holes are set again, and the design continues inwards in the plan with the same logic. This logic works until there is still room to locate the cut, which is typically copied from the library. Design parameters are saved during this design process, and the plan adopts automatically to any changes within t he parameters. So after any edition, the entire plan is automatically recalculated inwards from the contour-profile. The recalculation process also works when a theoretical tunnel profile is edited.

All design parameters, along with the cut, can be imported from any existing plan to a new design with a simple mouse-click.



Round bottom design logic: let's put the focus on where the pull-out of a round is determined.



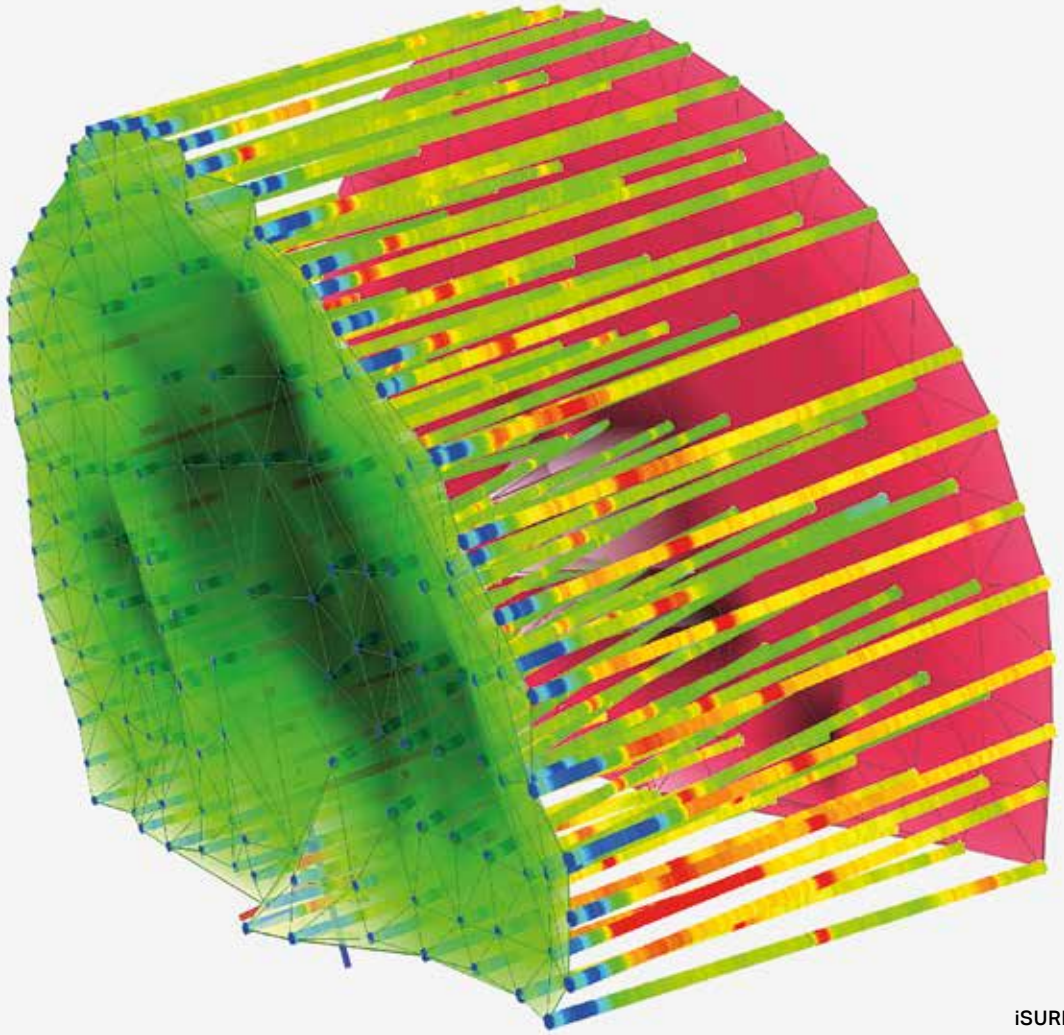
DATA COLLECTION PER ROUND

Rig usage and drilling process efficiency can be studied on a round by round basis. Counters for percussion, powerpack, drilled meters, net penetration and average and gross drilling capacity [m/h/boom] are collected for each boom. Gross drilling capacity figures provide information about the process as the time is measured from a rig's navigation until the finishing of the round.

A round's duration is divided into main categories for navigation, drilling, boom control, idle time, or booms not finishing the job at the same time – and further into sub-categories for drilling and boom. This provides valuable feedback that helps to tune the rig's behavior while acting as a learning tool for operators.

Drilled face and bolting holes are studied in 2D and 3D versus the plan and x, y, z coordinates of the start- and endpoints of the holes can be exported in the project coordinate system.

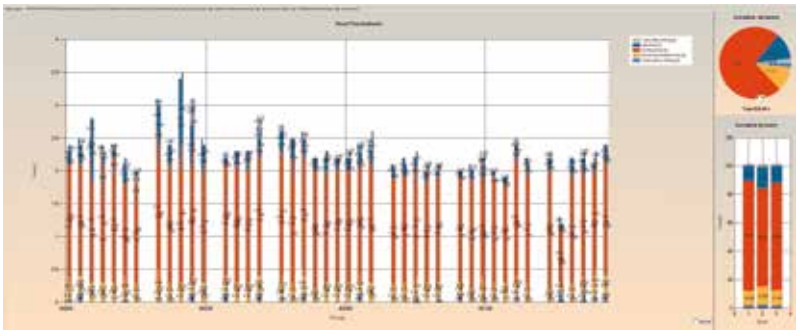
Measure While Drilling (MWD) records 19 variables as a standard to support both the reporting and tuning of drilling. This data can be reported as a word document or exported to formats like .csv, .xml or .dxf.



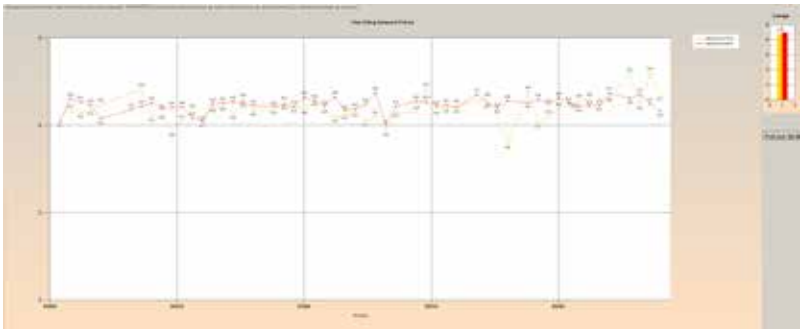
ANALYTICS BASED ON DATA COLLECTION

Analyzing data collection between any two advance (peg) numbers of tunnel line reveals the trends of different KPIs. Items like round time progress, variance in achieved drilling capacity, amount of drilled holes per round, the ability of operators to drill the holes into correct locations, and achieved blasting pull-out are good and fast indicators for tuning up your way of working when necessary.

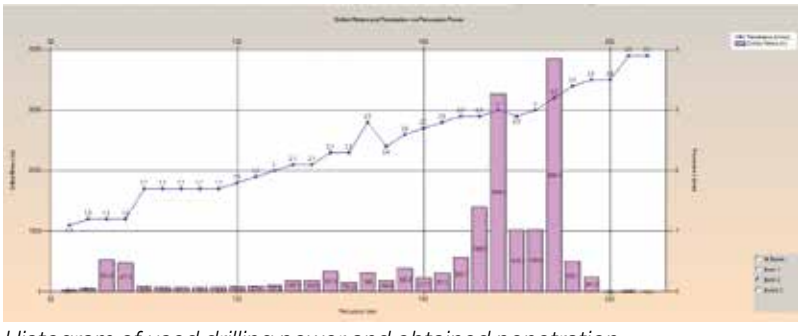
In addition to previous, analyzing Measure While Drilling (MWD) items gives a histogram report of the achieved penetration rate for the used drilling power, flushing sufficiency, or number of disturbances in drilling – both in general or between the booms.



Round time distribution of consecutive rounds.



Achieved pull-out trend.



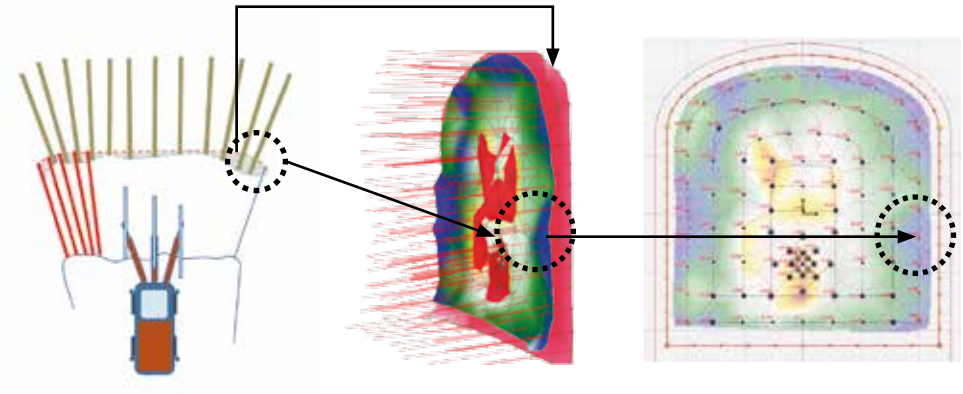
Histogram of used drilling power and obtained penetration.

IMPROVING THE PLAN – PULL-OUT FEEDBACK

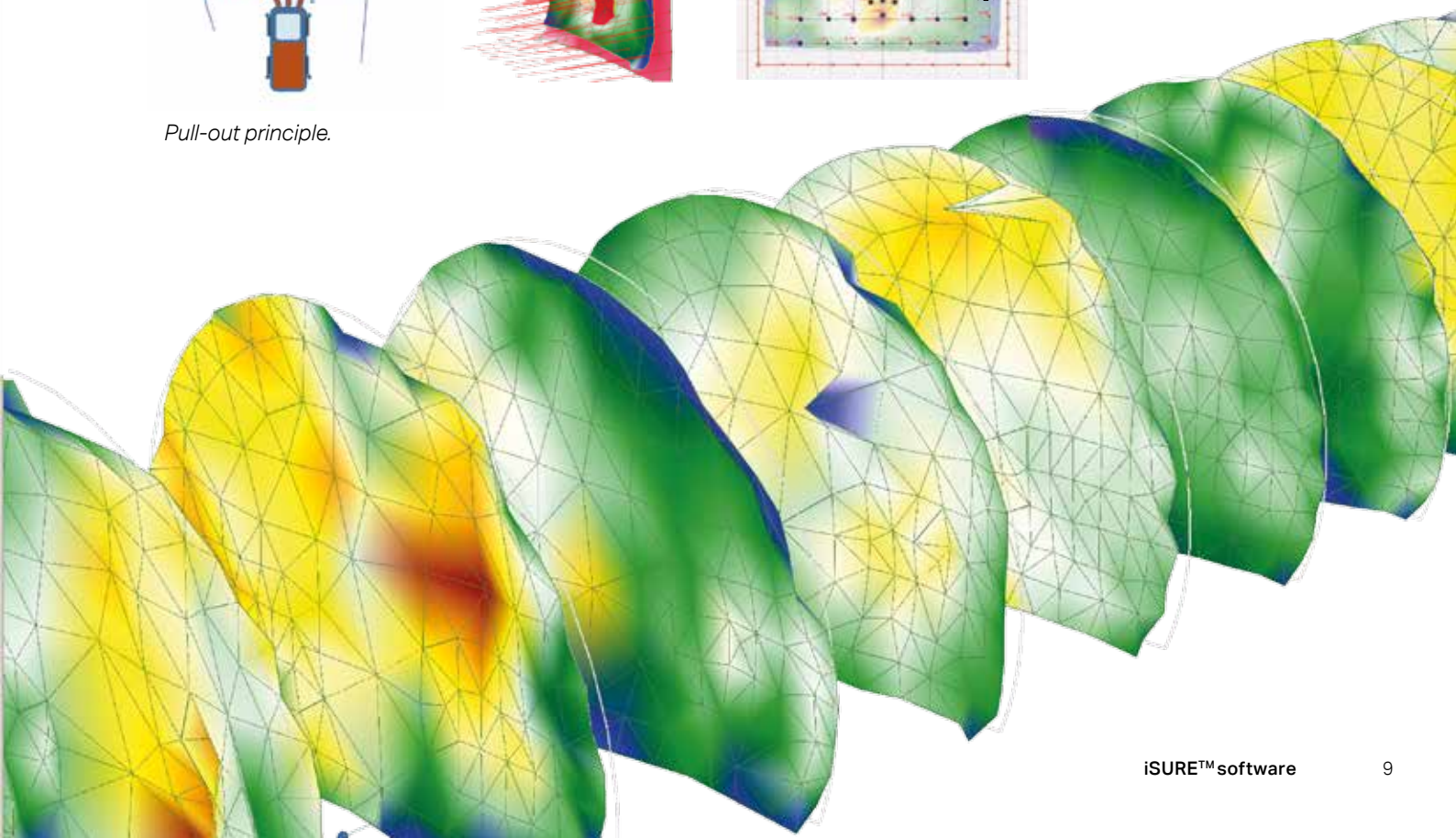
The achieved pull-out of each blast gives good feedback on the quality of the drill and blast plan. iSURE™ software uses a patented method to combine the realized feedback into the drill and blast design. This leads to maximized pull-out. The rig's data collection makes getting this feedback easy, as it records the start- and endpoint coordinates of each drilled hole.

A 3D pull-out map is generated by comparison of two consecutive rounds. Comparing the endpoint coordinates of the holes of the first round to the starting point coordinates of the next round results in a rock volume that was drilled but could not be blasted. This 3D information is then transferred as a color map on top of the original plan. The color map indicates just where to improve the plan.

To check that the pull-out situation remains consistent from round to round, the pull-out map is presented by a 3D-tunnel view (multiple blasts) as well.



Pull-out principle.

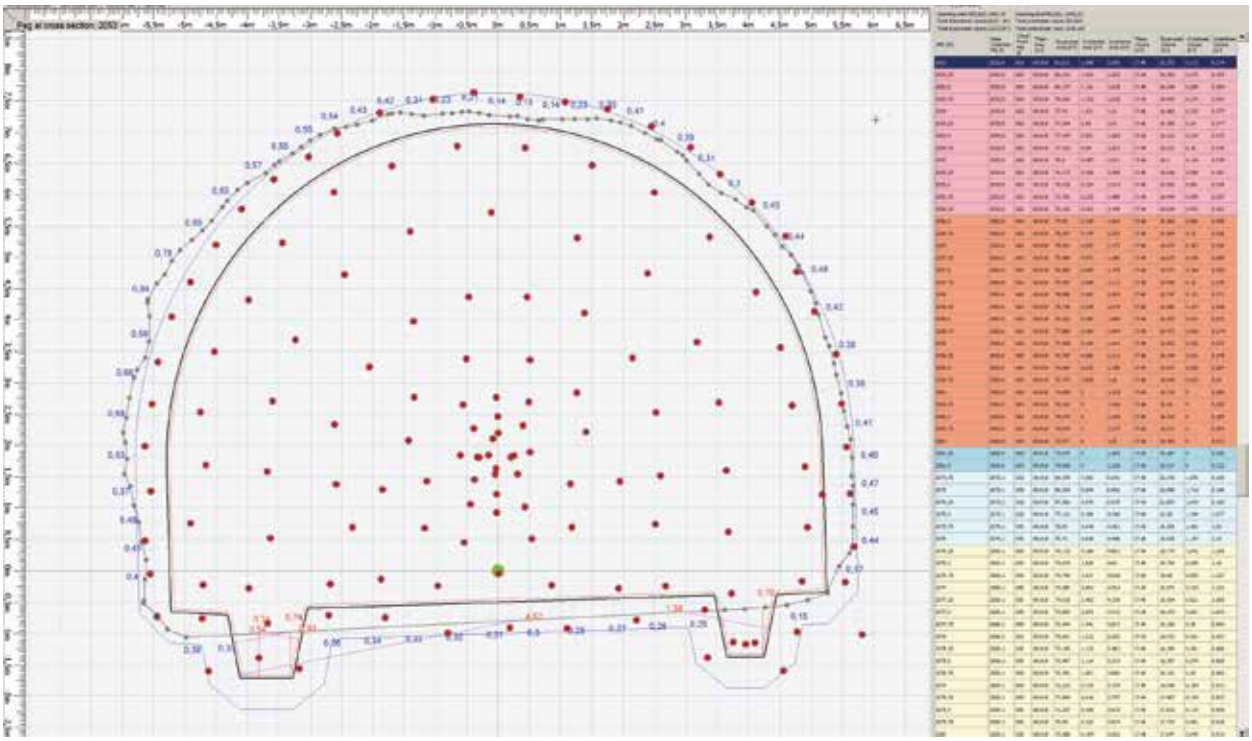


IMPROVING THE PLAN – ONBOARD 3D-SCANNER

To respond to more demanding excavation tolerances, both in construction and mining, the drill rig can be equipped with an onboard 3D-scanner. Scanning is run during the navigation procedure of the rig and it records a point cloud, which is visible from the rig's location, and creates 3D and 2D views onboard on the rig. Possible under- and overbreaks are visualized, and any under-breaks can be corrected together with the blasting of the face in question by drilling extra hole(s) to previous rounds' area.

The realized profile is vital feedback information for the drill plan development, as it is for getting the blasting result correct without any extra procedures. Recorded and automatically extra-object-filtered point clouds are copied from the rig to iSURE™ software. A tunnel point cloud model is visualized in 3D with colors indicating over- and underbreak, and break within tolerance.

To further analyze this feedback together with the drill plan and the actual holes that have been drilled, a realized cross-section profile from any advance of the tunnel is presented together with the holes. With this method, rock breakage along the contour holes is checked, and possible overcharging or geology problems are visualized among others.

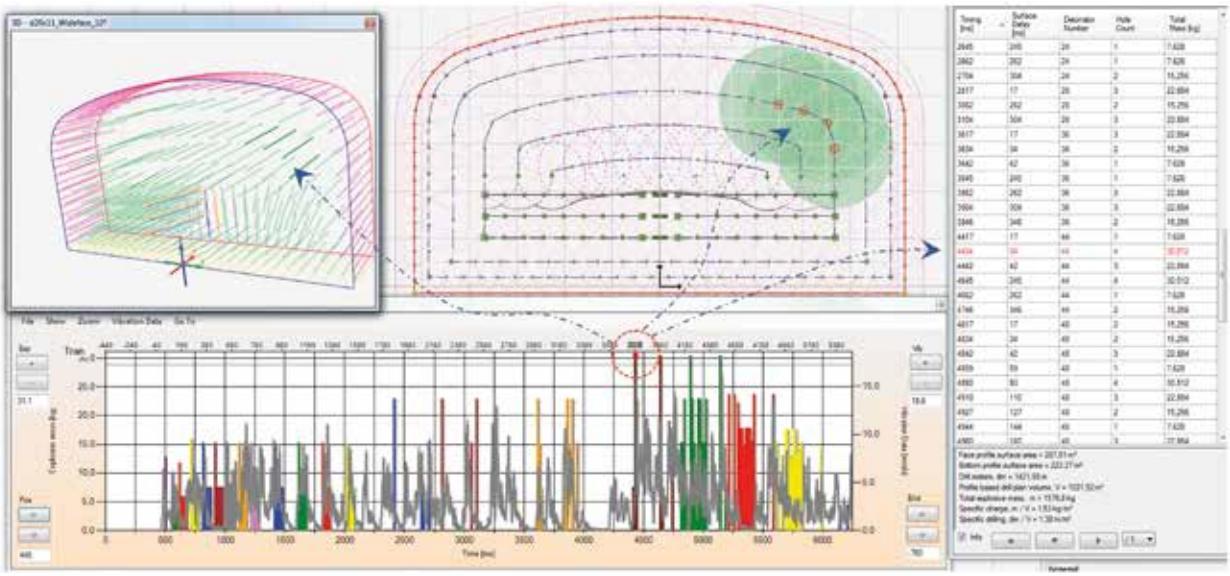


BLAST VIBRATION FEEDBACK

The control of the vibration generated by the blasting is a relevant factor in urban areas. Road tunnel profiles are typically large, and strict vibration limits yield into special detonation, short rounds, and/or partial face blasting. The last two hold back excavation progress and increase the costs.

iSURE™ software detonation timing – together with surface delay unit design – produces the momentary blasting information and a report (kg/ms) of the blast of each round. iSURE™ software also supports feedback of actual vibration (peak particle velocity) data generated by the blast. This data can be loaded on top of the momentary blasting information, and calibrated to correspond the planned kilos in order to reveal the possible overshoots/misfires in vibration (mm/s) data. This results in better control of the conditions in question.

iSURE™ software is able to interact with Blastview data format. Other 3rd party vibration measurement systems can be connected through an open .xml format.



Vibration data presented over the momentary information. Overshoot is pinpointed to holes in question and planned momentary kilograms are presented.

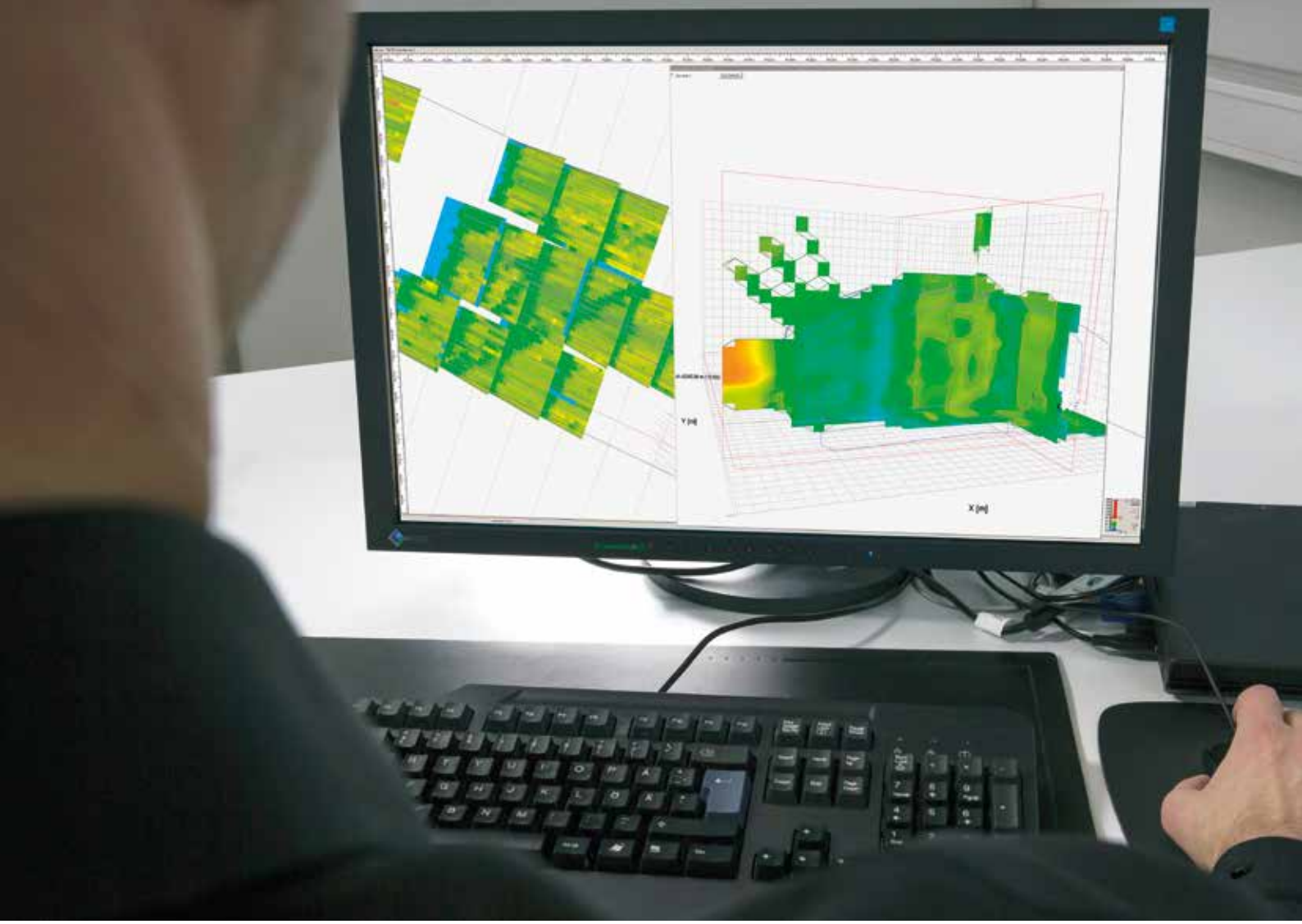
GEOLOGY INTERPRETATION – iSURE™ GEO

iSeries rigs with a GEO option produce Rock Mass interpretation based on percussive drilling. The requirements for this data can be conducted from:

- ✔ Underground projects can consist of uncertain elements. The cost of the project may be dominated by geology.
- ✔ Preliminary site studies may include insufficient information, such as the exact location of fault zones. Additional geological information increases the data coverage and can focus the way of working.
- ✔ Geology knowledge will reduce the risk of encountering unforeseen ground conditions during excavation.
- ✔ Geology knowledge helps to understand potential problems as well as their solutions. It gives you the means for predicting tunnel behavior during the lifetime of the tunnel.
- ✔ Detecting the limits of ore bodies in mining creates economical benefit.

iSURE™ GEO refines and visualizes GEO data sampled and calculated at high speed (10ms interval) by the rig. iSURE™ software interpolates data between the drilled holes. 2D visualization of tunnel is done in tunnel top, side and as unrolled profile views. 3D visualization enables the tunnel model to be examined through three cut planes.

ANALYSIS VARIABLE NAME	DESCRIPTION	VALUE RANGE
Fracture indicator	Indicates individual fractures 0%: No fracture 100%: Full fracture sample	0–100%
SDR (Sandvik drilling resistance)	Rock strength index, rock's resistance to drilling system	0–500 MPa
Rock class	SDR class, class tresholds set by user	1–8
Water indicator	Indicates the occurence of water during an indicated fracture 0%: Water unlikely 100%: Water likely	0–100%
Rock quality number	Indicates the 'in tactness' of rock 0%: No over 10cm intact samples 100%: In tact rock	0–100%
Rock quality class	Class of rock quality number, class thresholds set by user	1–8
Analysis validity	The estimated validity of analysis 0%: Not valid 100%: Fully valid	0–100%



iSURE™ GEO example. Top View with three rounds side by side, drilled holes and 3D view sliced in Y direction, one plane together with isosurfaces

DATA IS USED FOR

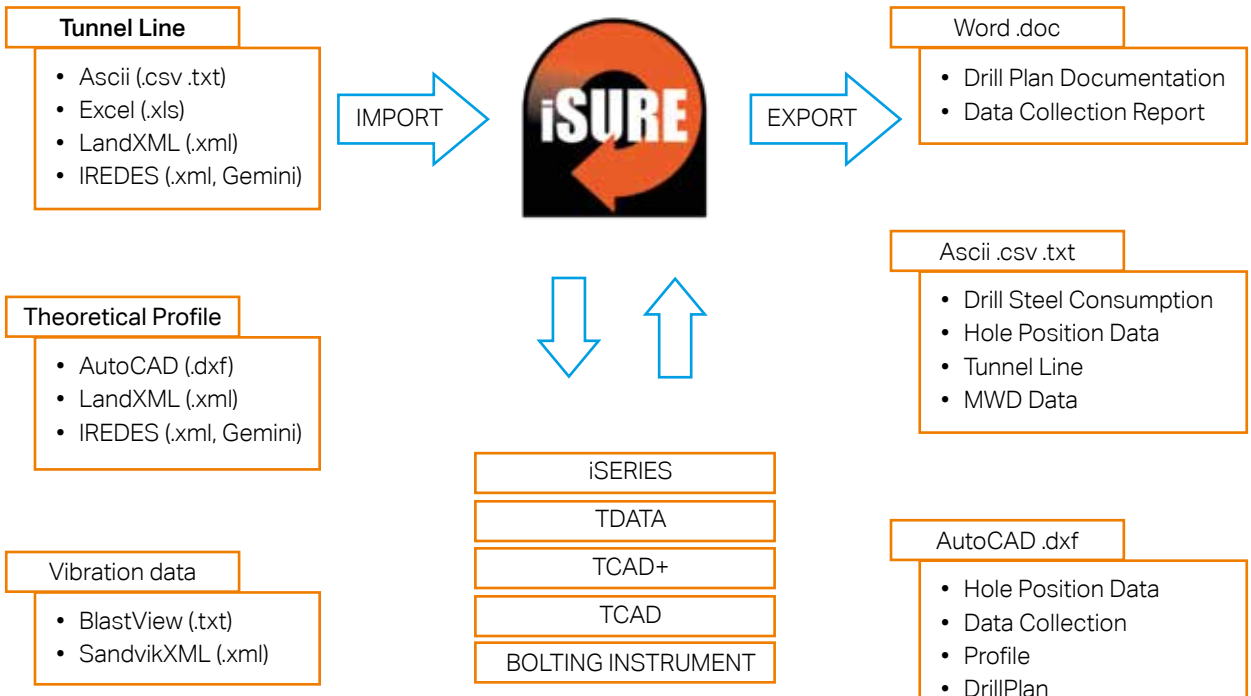
- ✔ geological mapping
- ✔ meeting contracting requirements
- ✔ assessing reinforcement needs
- ✔ assessing injection needs
- ✔ assisting blasting control
- ✔ easy reporting & documentation

DATA CALCULATED BY THE DRILL RIG IS PRESENTED IN iSURE™ SOFTWARE AS

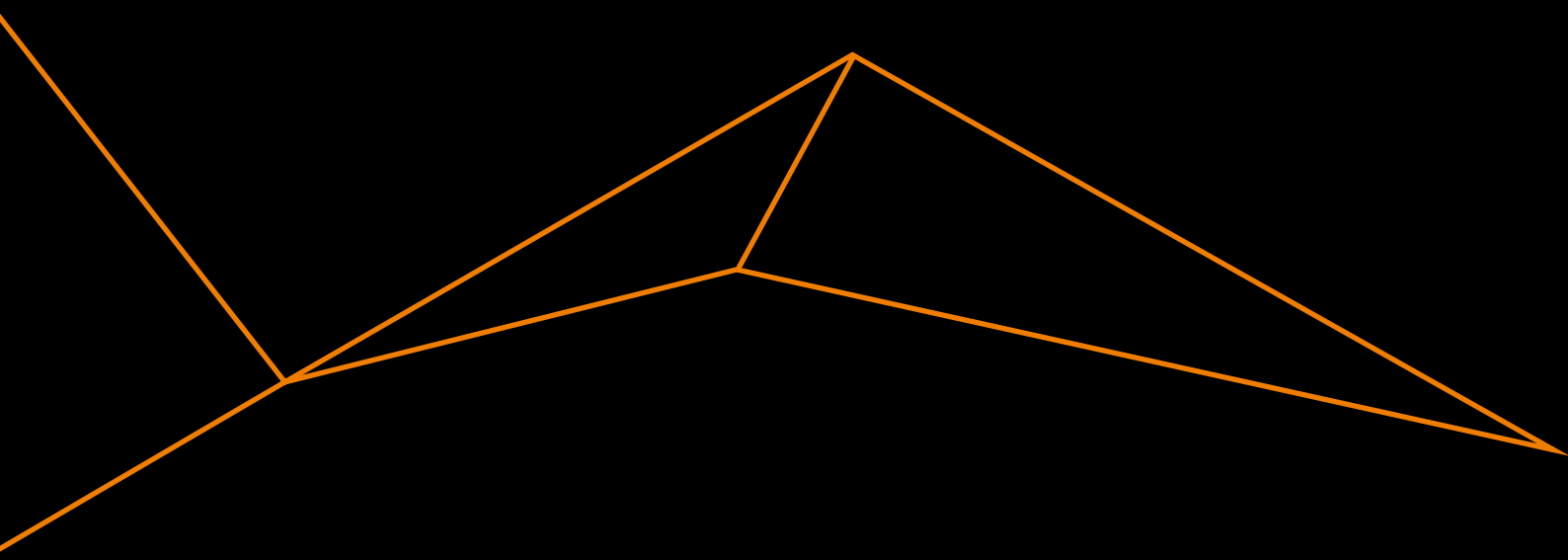
- ✔ 3D structural view with geo data interpolation together with x/y/z plane intersections, iso-curves and iso-surfaces
- ✔ tunnel-map view (2D) with top/side/rolled-out views
- ✔ hole by hole MWD graph

INTERFACE TO 3RD PARTY SYSTEMS

iSURE™ software offers a variety of file formats for importing and exporting data from and to third party systems.



Import / export formats



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