

White Paper

Graz, December 2011



3G Software & Measurement GmbH

Plüddemangasse 77
A-8010 Graz, Austria
Tel. +43-316-464744
Fax: +43-316-464744-11
office@3gsm.at
www.3gsm.at



BlastMetriX^{3D}

**Bench face surveying and blast planning
using 3D images**

Our Ref: BMX_Info_en_v3.6
By: 3G Software & Measurement

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1 What's it about?

“We need safety and efficiency in mining operations!”

One of the fundamental problems in surface blasting is the lack of accurate knowledge on the geometry of the bench face and the blast site. Consequences are excessive vibrations, fly-rock, hard digging, boulders, bench damage, air blast, non-uniform fragmentation, higher strip mining costs, poor crusher throughput, or simply wasting money during every day of production.

Based on 3GSM's technology for generating 3D images from freehand taken photos, the University of Leoben, Mineral Abbau GmbH, and 3G Software & Measurement GmbH formed a joint venture in 2004. The goal was to develop a surveying system that provides a quick, easy, comprehensive, and effective acquisition of bench faces and allows for improved blast planning.

The result is called BlastMetriX3D and it fulfils these requirements and overcomes abovementioned drawbacks.

BlastMetriX3D

- **increases working safety** (by contact-free measurements)
- allows **optimised loading** and thus **more economic blasting** (reports on reduced production costs exist)
- provides a **reproducible documentation** of the excavation works by the 3D image (conservation of evidence) unachievable by other surveying technologies without images
- allows **blast planning and** estimation of the **geologic conditions** in one step

The system received several awards due to its innovative strength and quality.

The major distinctions to conventional surveying are:

1. A 3D image describes a surface accurately by a real image plus several hundreds of thousands of 3D measurements.
2. A 3D image clearly shows the actual geological conditions of a bench face.
3. Data acquisition is fast.
4. No special surveying skills or instrumentation are required.

The major distinctions to other 3D measurement technologies:

1. Very fast data collection on site
 2. No bulky, expensive hardware
 3. Objective and reproducible documentation of the rock mass conditions
 4. System also works when it's raining or snowing
-

3GSM – Simply Measure!

2 Overview

The basic components of BlastMetriX3D are: (i) an imaging system, (ii) marking elements, and (iii) software components (see Figure 1).

BlastMetriX^{3D}

Principle: 3D images (Stereo-Photogrammetry + Computer Vision)

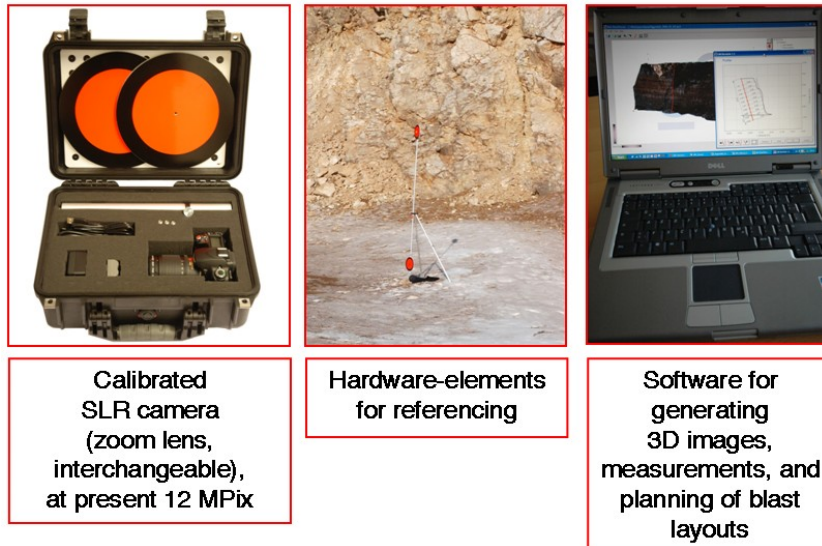


Figure 1: Components of the BlastMetriX3D system. The camera is pre-calibrated for ensuring accurate measurements and stored in a protection case.

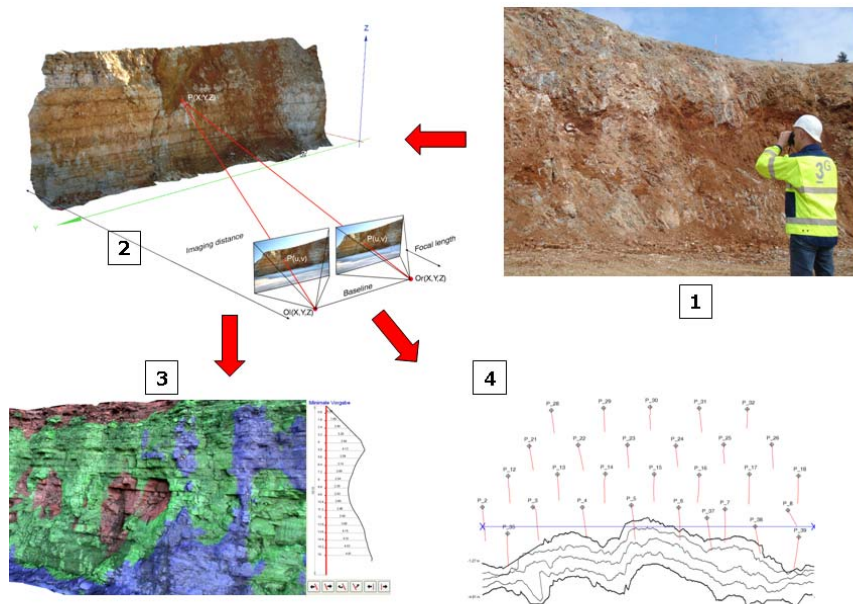


Figure 2: BlastMetriX3D principle: From a set of photos (1) a 3D image is computed (2); burden information over the whole area (3) is used to adapt the drill layout according to the actual bench face geometry; the results are profiles, minimum burden diagrams, and a drill pattern (4).

3 How to plan an optimal shot with BlastMetriX3D

The application of the system with the most value to the customer follows the following procedure:

1. Establish marking elements in the area to survey
2. Take two pictures with the calibrated camera from slightly different locations (stereoscopic image pair)
3. *Optional:* Survey the location of the marking elements, e.g. by total station or accurate GPS; only if geo-referenced surveys are required.
4. Compute a three-dimensional image using the BMX Reconstructor software
5. Specify intended drill pattern
6. Check the resulting burden situation with the capabilities of the BMX BlastPlanner software
7. Relocate holes to fit geometric irregularities of the bench face with instant graphical update to burden information; consider in additional the visual assessment of bench face quality → **optimised blast site**
8. Print the result and stake out the planned (optimised) drill pattern
9. Drill the layout
10. *Optional:* check the location of the drilled boreholes and update the planning
11. *Optional:* check the deviations of the drilled boreholes using down-the-hole probes and update the planning
12. *Optional:* do a comparative 3D image (if bench face might have changed between first survey and loading time) and update the planning
13. Use final profiles including minimum burden diagrams, sectional areas, etc. for the loading
14. **Get an optimal shot**



4 BlastMetriX3D details

4.1 3D image generation

The principle behind BlastMetriX3D for getting three-dimensional information is digital photogrammetry enhanced by modern algorithms from computer vision. The implemented modern algorithms allow the use of an off the shelf digital camera equipped with zoom lens and freehand application without any external surveying. The results are so-called 3D images.

A 3D image is a digital photo combined with spatial information on the objects/surfaces it shows.

The generation of a 3D image is supported by software components that guide through the whole reconstruction process. Once all boundary conditions are defined by the operator, the 3D image is computed automatically.

Figure 3 schematically shows how three-dimensional measurements are gained from a stereoscopic image pair. A crucial step is the automatic identification of corresponding points within the image pair. Note that the photos show the same part of a rock face since measurements are only possible in those regions.

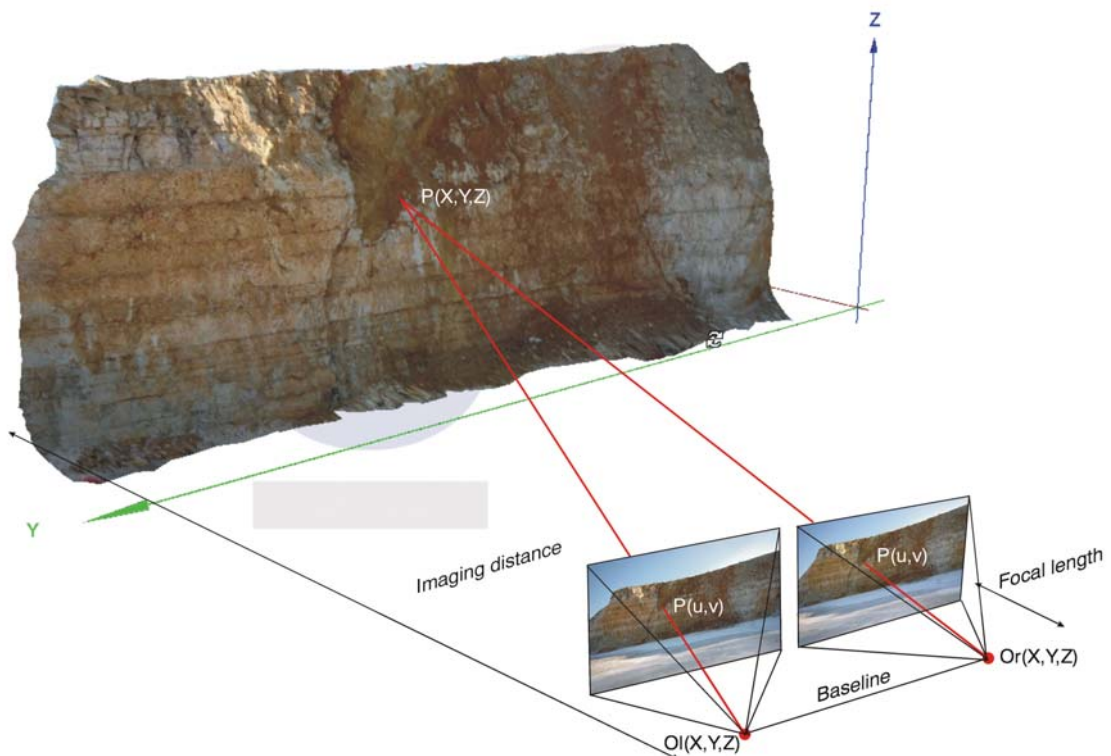


Figure 3: Generation of a 3D image: from a pair of photos taken from different angles the geometry of the observed surface is automatically reconstructed. Modern algorithms do not need knowledge on the baseline or camera locations.

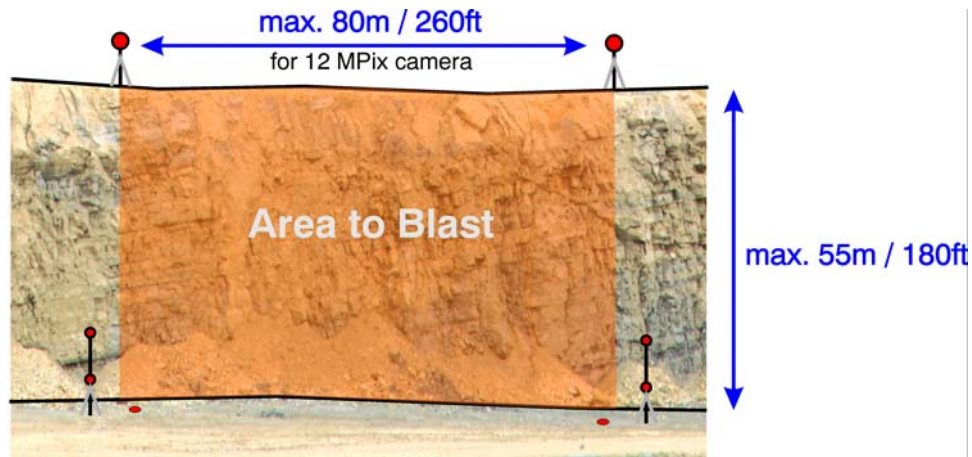


Figure 4: The typical working range for a single 3D image depends on the number of pixels and the size of the marking elements. The indicated range is valid for a 12 Megapixel camera and standard sized marking elements.

Practical applications often involve dealing with larger areas or complex shapes (corners) which goes beyond the visible information available from a single stereoscopic image pair. In such cases, the rock wall is acquired by several overlapping 3D images. With the optional BMX ModelMerger software component they are automatically aligned to a larger 3D model based on common structural and topographic information in the overlapping area of the 3D images (see Figure 5).

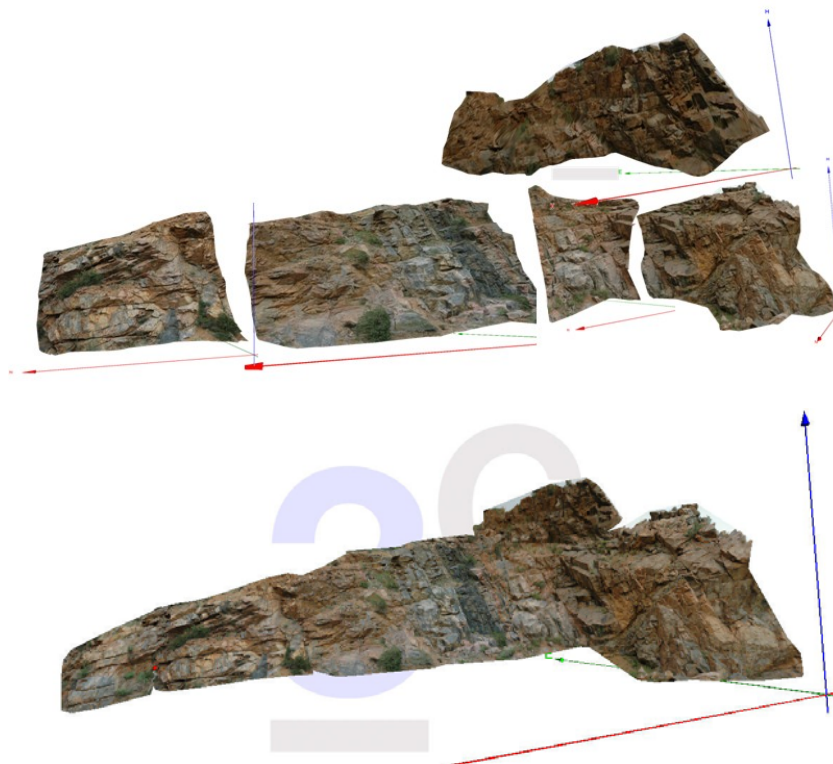


Figure 5: Several overlapping 3D images (top) and merged result (bottom). All pictures were taken freehand without surveying any camera station.

4.2 Planning an optimal blast

Once the 3D image of a bench face is ready the planning of the blast is performed using the **BMX BlastPlanner** software.

By entering basic geometric parameters such as burden, spacing, or inclination of the boreholes the system places them accordingly. Each borehole gets a profile as well as the sectional area, and the minimum burden diagram.

The determined borehole locations are visualised three-dimensionally as well as in plan view.

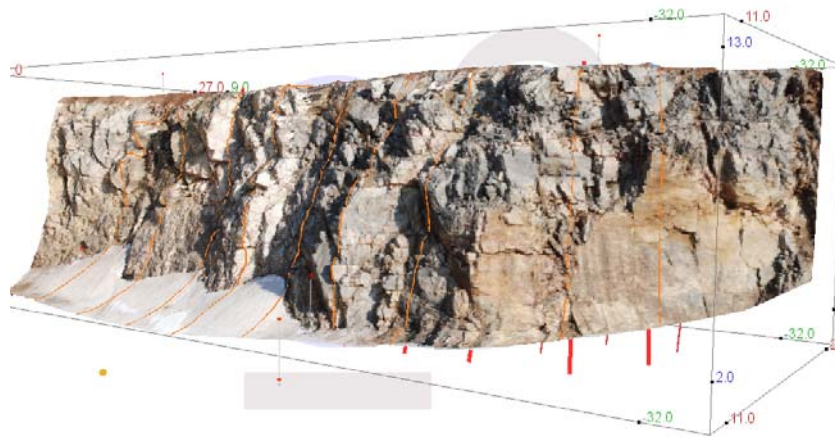


Figure 6: 3D image of a bench face around a corner together with planned boreholes and visualised profiles. The 3D image allows for a visual assessment of the rock mass quality, e.g. identification of higher fractured areas or potential weaker zones.

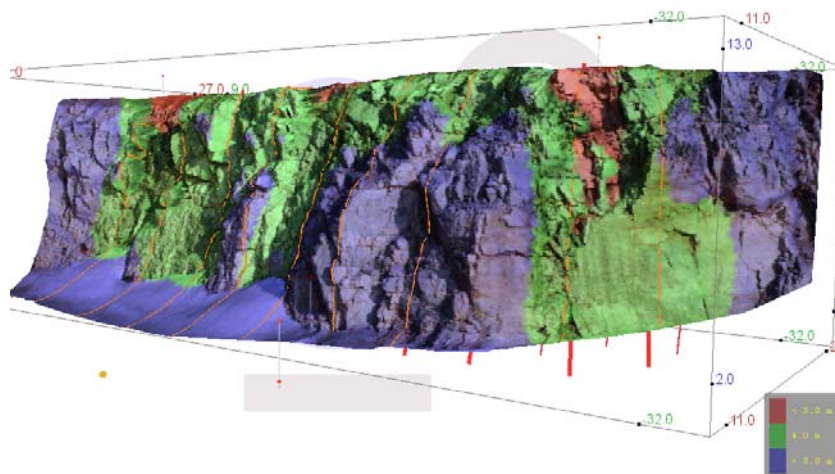


Figure 7: A (configurable) colour coded visualization of burden over the entire bench face facilitates the identification of light burden zones (red).

The relocation of single boreholes according to the actual bench face geometry is the key step in the optimisation procedure. The optimisation effects become even more evident for irregular shaped bench faces that include cavities, weak zones, or at free ends and corners.



Figure 9: 3D image of a bench face

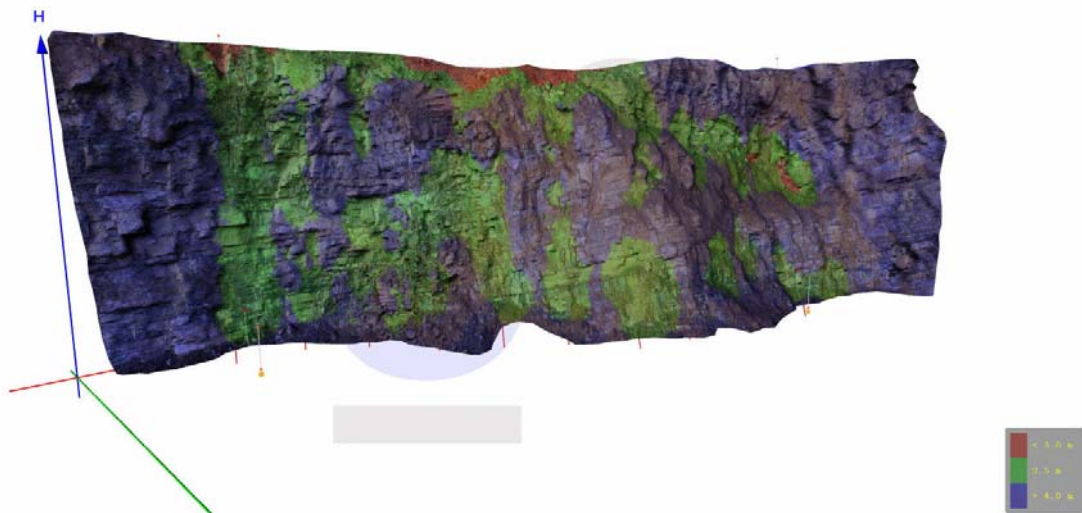


Figure 10: Burden information over the entire face

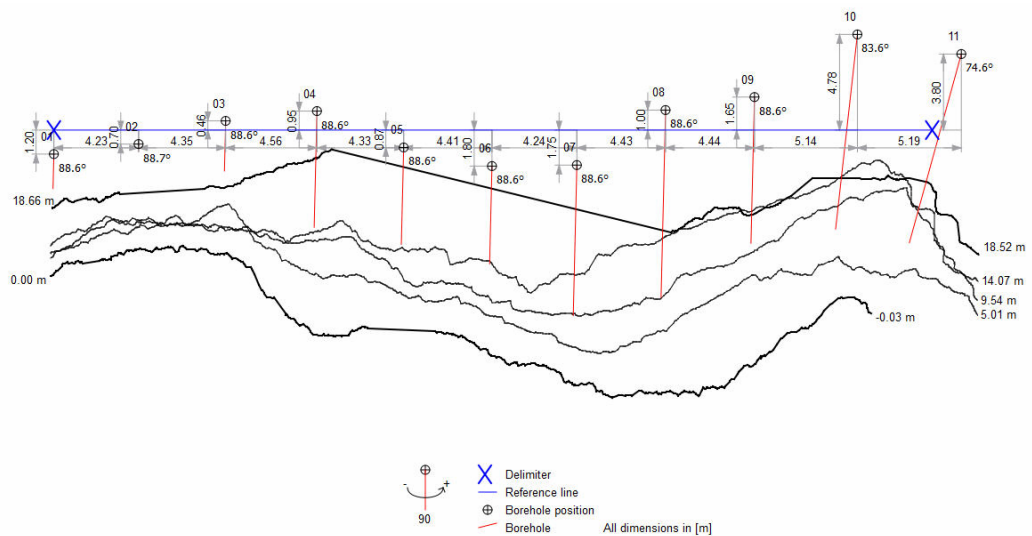


Figure 11: Plan view

4.4 Import of borehole deviation data

The complete geometry of a blast site includes the geometry of the bench face and the boreholes. To ensure the validity of planning the real location of the shot hole collars as well as the trajectory of the holes must be surveyed.

Several down-the-hole probes exist. Their results are imported into the BlastMetriX3D software which updates the blast site and the burden information accordingly.

4.5 Profiles vs. Minimum burden diagrams

Profiles are generated by intersection of a plane and the free surface of the bench. Consequently, a profile does not necessarily show the shortest distance from the borehole to the surface.

A minimum burden diagram plots this shortest distance from a search in any spatial direction, i.e. spherically around any location of the borehole.

However, loading of the holes shall base on the minimum burden information.

For irregular bench faces containing cavities, at free-ends, or corners a significant disparity between the profile and the according minimum burden diagram may occur (see Figure 14).

Fly rock often occurs in conjunction with overestimated burden – a minimum burden diagram visualises the crucial information to that. Pure profiles might hide light burden situations even when several adjacent profiles are taken into account.

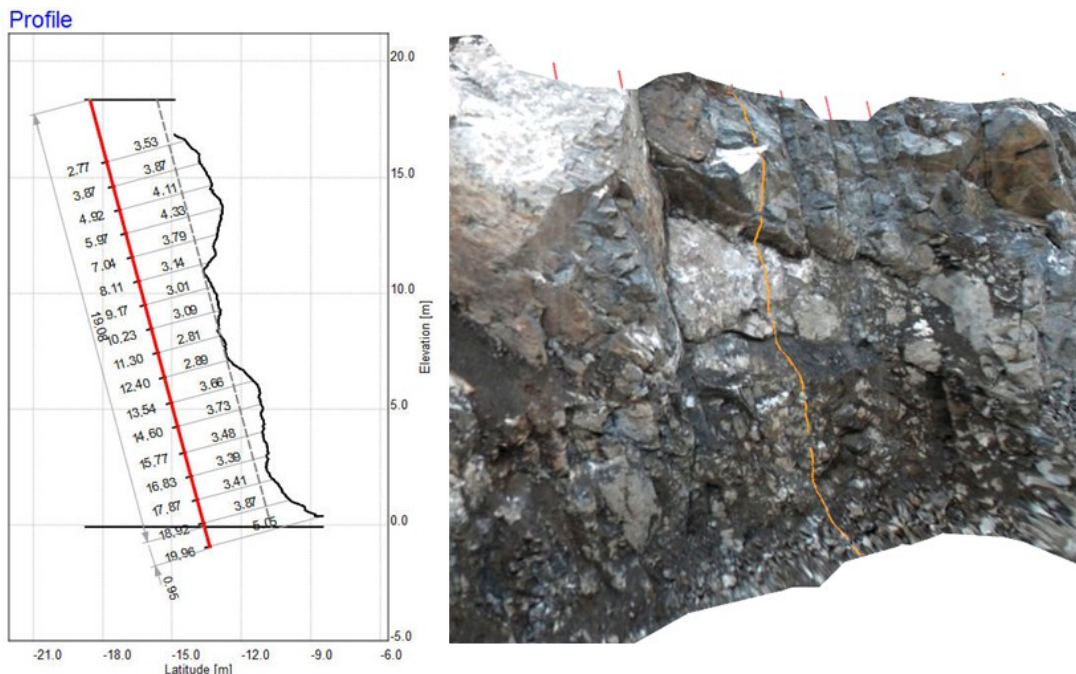


Figure 12: Profile as it occurs from intersecting a plane with the bench face.

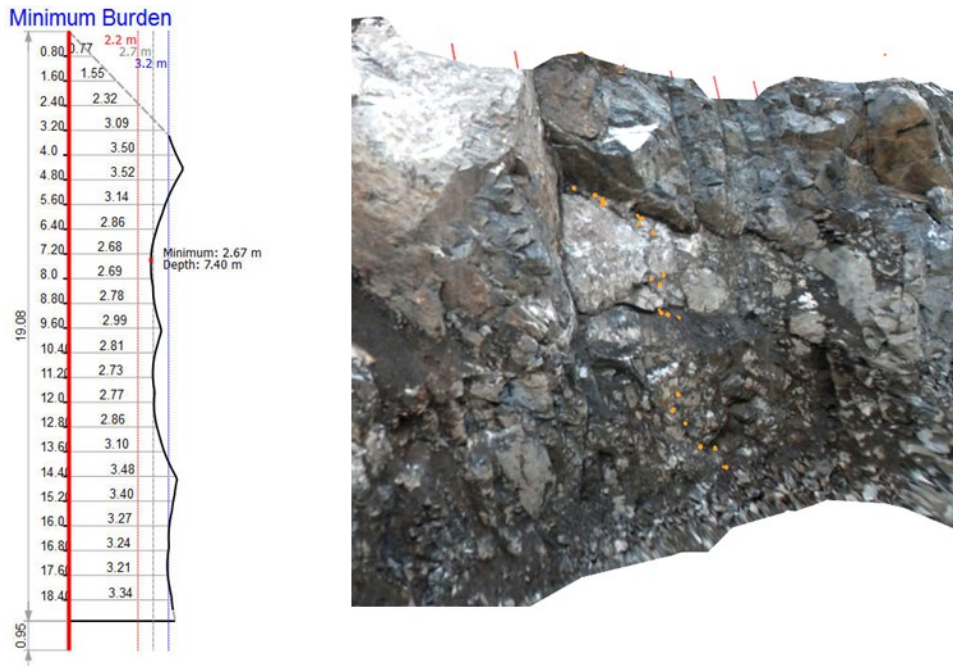


Figure 13: The minimum burden diagram provides the shortest distance to surface regardless in which spatial direction. The locations on the surface where minimum burden occur (orange dots) might significantly deviate from where the profile appears.

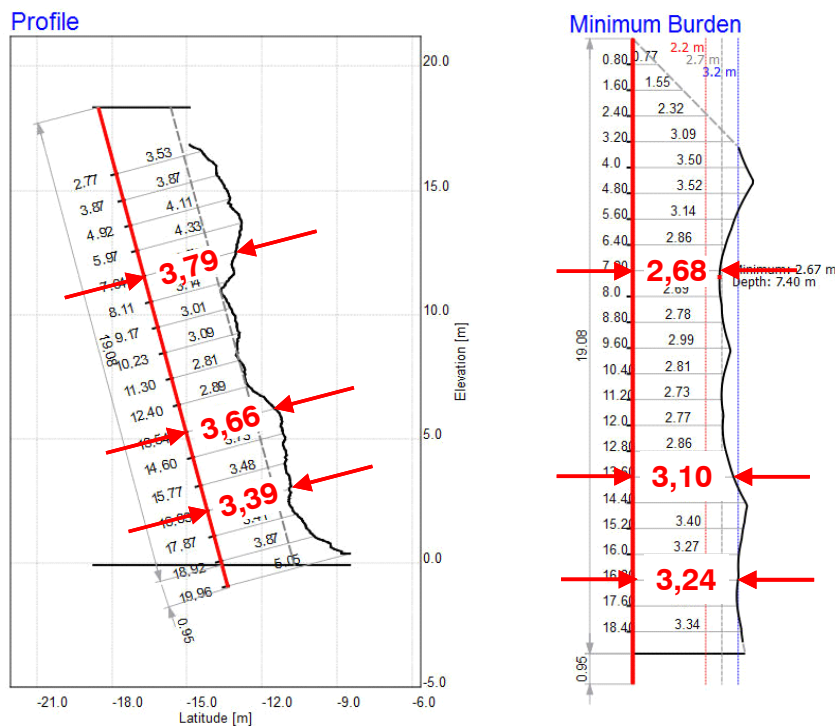


Figure 14: The profile and minimum burden diagram for the same shot hole show discrepancies. A profile might overestimate the real burden situation significantly.

4.6 Uneven crest

BlastMetriX3D allows considering an uneven crest by using so-called top level surface markers. They are placed along the crest line in a way that they are visible in the stereoscopic image pairs. Natural markers such as monuments might also be used though automatic target centring is then not supported. Furthermore, surveyed terrain points at the crest are importable in order to refine the shape of the top level surface. Planned and imported boreholes follow the top level surface (see Figure 15).

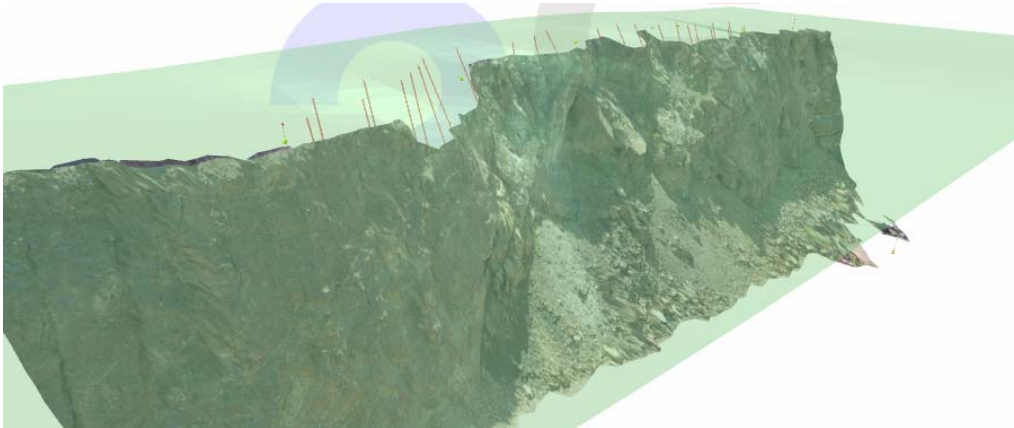


Figure 15: 3D image with enabled top level surface modelling an uneven crest.

4.7 Economic impacts

Optimised blast sites lead to more efficiency. In the following some exemplary figures are given showing the savings of one particular customer achieved through an optimisation procedure including the use of BlastMetriX3D. No 3GSM personnel were involved in the study at any phase. The found results include:

- Increase of the regular drilling geometry by 15% (burden and spacing)
- Reduction of the manpower for drilling by approx. 10%
- Better fragmentation judged by visual estimation
- Less costs for strip mining service (less reduction of boulders)
- Decrease of specific explosives consumption by 9%
- Decrease of electricity consumption in the crusher by 16%
- Increase of crusher throughput by 8%

5 Scope of delivery

5.1 BlastMetriX3D hardware components

See also Figure 16.

BMX ImagingSystem

- Nikon D90 digital SLR (single lens reflex) camera with 12.3 Megapixel, calibrated
- Tamron 17-50 mm zoom lens, calibrated
- Sigma 10-20 mm wide angle zoom lens, calibrated
- Calibration panel
- 2 delimiters with one target disc Ø 35 cm each
- 2 range poles with two target discs Ø 25 cm each
- 5 top level surface markers with one target disc Ø 28 cm each
- Delivered in watertight, dustproof case (camera) and carrying bags (delimiters, range poles)

Hardware extension (for BlastMetriX3D Supreme)

- 1 additional delimiter with one target disc Ø 35 cm as top-level marker
- 2 additional targets Ø 25 cm as floor-level markers



Figure 16: Camera in case (left), range pole (middle), top level surface marker (right top), delimiter (right bottom).

Notebook computer

The notebook computer shall be seen as integral part of the measuring system. It ensures system performance (3D graphics) and facilitates potential support. Installation of software and updates requires administrator privileges.

Current model (December 2011): Dell Latitude E6520: Intel Core i5, 2.50 GHz, Windows 7 Professional 32-Bit English, 4 GB RAM, NVIDIA Quadro NVS 4200M 512 MB, 320 GB HD or better.

5.2 BlastMetriX3D software components

BMX Reconstructor

Software for generating metric (scaled) 3D images from photos taken with the BMX ImagingSystem comprising the components: BMX ReconstructionAssistant, BMX SurfaceTrimmer and BMX BlastSiteGenerator. Also included is the BMX CalibrationTester, a component for checking the condition or camera calibration. The resulting 3D image is a comprehensive documentation of the blast site.

BMX BlastPlanner

Software for geometric planning of a blast in context with a 3D image of the according bench face. The software provides among others the geometry of the bench face (exportable as DXF), profiles, minimum burden diagrams, burden information over the entire bench face, cross sectional areas per borehole, as well as a drilling plan.

SMX Referencer (only with *Supreme* configuration)

Software component for transforming a generic 3D image into a geo-referenced, metric 3D image using surveyed reference points with known 3D co-ordinates.

BMX ModelMerger (only with *Supreme* configuration)

Software for merging several 3D images into one larger 3D model. The component can merge up to six 3D images into one model which is used to acquire large blast sites or complex shapes (e.g. free corners). The software smoothly interacts with the BMX Reconstructor and BMX BlastPlanner software components.

5.3 Updates and support

Updates of the BlastMetriX3D software are provided via 3G Software & Measurement's webpage under www.3gsm.at. Data for performing support for a single survey is also transferred via this webpage.

With an active support license 3G Software & Measurement helps via email and remote desktop support (webmeeting), and provides limited camera replacement service after availability.

5.4 BlastMetriX3D shipping packages

There are two pre-configured packages related to the BlastMetriX3D system.

BlastMetriX3D Express is the standard, “ready to go” bench face surveying system.

It includes:

- BMX ImagingSystem
- Notebook Computer
- BMX Reconstructor Software
- BMX BlastPlanner Software
- SU License BMX: Service and Updates for one year
- 1 day training for up to three persons in Graz, Austria

BlastMetriX3D Supreme includes additionally the model merging option, i.e. larger blast sites or corners are surveyed with it.

The package includes:

- BMX ImagingSystem + Hardware extension (additional markers)
- Notebook Computer
- BMX Reconstructor Software
- BMX BlastPlanner Software
- BMX ModelMerger
- SMX Referencer
- SU License BMX: Service and Updates for one year
- 1 day training for up to three persons in Graz, Austria

BlastMetriX3D Express can be upgraded for georeferenced measurements through inclusion of the 3D registration software SMX Referencer.

Any BlastMetriX3D can be upgraded to geotechnical mapping system through inclusion of the 3D mapping software component JMX Analyst.

For individual configurations contact 3G Software & Measurement at office@3gsm.at or your service partner

6 Specifications

Data acquisition

| | |
|------------------|--|
| Working range | Bench face size: 80 m (width), 55 m (height) (standard) Larger areas using the BMX ModelMerger option |
| Imaging distance | 10 m -150 m (standard) Up to 750 m with telephoto lens (on request – special configuration) |

Hardware

| | |
|--------------------------|---|
| Camera | Nikon D90, 12.3 Megapixel SLR camera (by December 2011) shipped in watertight dust-proof protection case other models on request |
| Camera calibration | Camera is calibrated on delivery – calibration status can be checked on site anytime by taking images of the included calibration target. Time cycle between recalibrations depends on camera treatment; suggested: 12 months |
| Range pole | Scaling element consisting of a bipod, a pole with a spirit level and two signal discs mounted at known distance |
| Delimiter | Marking element consisting of a tripod, a pole with a spirit level, and a single signal disc |
| Top level surface marker | Marking element consisting of a plastic cone and one signal disc at known height |

Application

| | |
|---------------------|---|
| Measuring principle | 3D images generated by photogrammetric and enhanced computer vision algorithms |
| Blast planning | Purpose made BMX BlastPlanner software; includes 3D representation and navigation, various possibilities to optimise the drill pattern according to the bench face geometry, import of borehole survey data |
| Results | 3D images in local or geo-referenced co-ordinates Printable report (PDF) with scaled plan view, profiles, minimum burden diagrams 3D images are conveyable to third party using free BMX Inspector software |

| | |
|-------------------|---|
| Time need | The time need from taking the photos, generating the 3D image, optimising the layout, and generating the report including the borehole plan is less than 2 hours (typ.). |
| Geo-referencing | Requires at least 3 control points (points with surveyed co-ordinates) in the imaging area Alternatively two camera stations and one reference point in the imaging area ca be used Requires optional SMX Referencer software |
| North-referencing | Exists inherently when using reference points Alternatively the azimuth of the reference line (connection between delimiters) is used to reference a bench face to north without needing surveyed points. |
| Accuracy | cm range for typical applications in the standard working range |
| Unit format | Configurable to m, mm, ft, inch |
| Data formats | 3D image: proprietary data format containing geometry and visual data, as well as all information on 3D image generation. Blast site: proprietary XML style file containing all blast site related information. |
| Data export | DXF, CSV Other formats on request |
| Languages | English, German Other languages on request |

Subject to change without notice

The system received several awards due to its innovative strength and quality.

