5th International Conference & Exhibition on Mass Mining

Luleå, Sweden

9-11 June 2008

Håkan Schunnesson
Erling Nordlund
editors

LULEÅ UNIVERSITY OF TECHNOLOGY

Proceedings of the 5th International Conference and Exhibition on Mass Mining / Luleå / Sweden / 9-11 June 2008

MassMin 2008

Edited by

Håkan Schunnesson

Erling Nordlund

Luleå University of Technology, Sweden
Division of Mining and Geotechnical Engineering

LULEÅ UNIVERSITY OF TECHNOLOGY

The Head of Division of Mining and Geotechnical Engineering
Luleå University of Technology
971 87 Luleå
Sweden
E-mail: erling.nordlund@ltu.se

ISBN 978-91-633-2331-7

Printed by: Luleå University of Technology Press, Luleå, Sweden

The introduction of IT into mass mining: the digital mine in Hambach surface mine

Robrecht M. Schmitz *Hambach surface mine, RWE-Power, Germany*

U. Kübeler *Hambach surface mine, RWE-Power, Germany*

F. Elandaloussi *Syperion, Bremen, Germany*

D. Lau *Aucoteam, Berlin, Germany*

R-J. Hempel *Hambach surface mine, RWE-Power, Germany*

Abstract

Driven by the challenge to continuously improve mining processes, Hambach surface mine spearheaded with the concept of the digital mine: one database in which all existing relevant spatial data (mine plans, position of wells, position of excavators and spreaders etc.) is collected, processed (automatic update of the digital terrain model by monitoring the stacking and excavation process on-line) and made available (informative, interactive) to excavator and spreader operators in the mine and to mine planners, engineers and managers in the mine HQ. The digital mine makes the complex dynamic mining processes transparent and guarantees data consistency, irrespective through which window the different users make use of, and work with the digital mine.

1 Introduction

This paper focuses on the introduction of the concept of the digital mine as an optimisation tool in a surface mine near Cologne Germany. The mine, called Tagebau Hambach (Hambach surface mine), is the world's largest lignite mine. The introduction of the digital mine in Hambach surface mine describes the introduction of IT into mining, not as a sensor to measure heat development of a piece of mining equipment, but as a tool to bring (foretold by NF 2000) more and more components of a mine operation "on-line", and to link them through mine wide communications networks and GPS based dispatch systems, to optimise the entire mining process. An inquiry (NF 2000) among industry leaders revealed that unit-operations technologies in the mining industry are unlikely to change radically in the coming two decades. What is likely to change is how unit-operations will be managed. This can be achieved through the digital mine described in this paper.

2 Hambach surface mine

Hambach surface mine, one of three open-cast mines in the region operated by RWE-Power in North Rhine-Westphalia, follows a long tradition of lignite mining in this region. Lignite is used to produce more than 50% of the electric energy required by the industries and cities in North Rhine-Westphalia (18 million inhabitants, one of the 15 most important economic regions in the world). The mining district is located in between two „branches“ of the Rhenish Slate Mountains. During the Tertiary, the Rhenish Slate Mountains were weathered down. The sediments were transported and deposited by rivers traversing the plane area - which was subjected to tectonic subsidence - towards the North Sea. Lush vegetation developed on this plane and along the coastline. During trans- and regressions, processes promoting the development of marshes (Pohl 1992), the dying organic material turned into peat. Due to subsidence of the plane, thick (400 m) peat layers accumulated (Walter 1995). This peat was transformed into 100 m thick lignite deposits. Sand, clay and gravel accumulated during the remainder of the Tertiary and the following Quaternary, resulting in a several hundred meter thick overburden. Loess was deposited on top of these layers (ENB 2005). In the 18th century the lignite deposits close to the surface were mined by manual labour. At the beginning of the 20th century mechanisation started. The bucket wheel excavators (BWE), conveyor belts and spreaders, developed in close cooperation with the mining societies in the region, became more and more sophisticated during the 20th century. In the 1970's the largest BWE ever built (operating weight: 13,000 metric tons;

production in sand: 240000m³/d) were constructed on the site of the present Hambach surface mine. Today these machines are still in operation and will be in action well into the 2040's when the last of the lignite will be mined in Hambach surface mine.

3 The mining process

The required annual lignite production in Hambach surface mine, amounts to 40 million metric tons. With the current stripping ratio of 1 to 6, more than 240 million cubic meters of overburden have to be mined, transported and stacked each year. The major part of the excavated overburden, and after 2009 all of the overburden, will have to be deposited on the inner dump. Because of the size of the excavation equipment, not every sand and clay layer can be mined separately. Therefore mixtures of sand/silt and clay dominate in the daily overburden disposition. Depending on the water content, the relative content of sand to clay in these mixtures, the transportation distance from excavator to the spreader, the mixtures are thoroughly remoulded and, inherently, their consistency will change. The inner dump has a total height of 600 m, measured from the top of the dump to the footwall. The stability of this slope is very important. Therefore remoulded (weak) clay-sand mixtures cannot be stacked straightaway on the dump without taking any preparatory measures. The method used in Hambach to overcome this problem consists in creating large sand basins (length parallel to the conveyor belt: several km; height: up to 15 m; width: 70 to 90 m) on a spreader bench (A1 in figure 1), behind which the weak clay and weak clay-sand mixtures are stacked (B1 and C1 in figure 1).

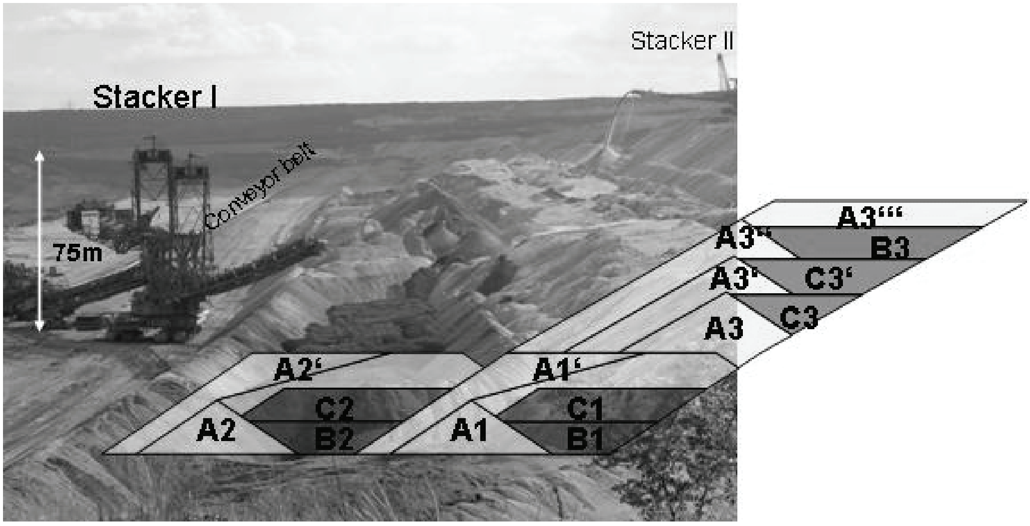

Figure 1 **A view of a spreader bench. Two spreaders, I and II working on different benches are in operation. An example of the possible geometries overlaid on the photo illustrates the complexity of the build up of the inner dump.**

The clay basin must be covered (A1' in figure 1) by sand, or sand-clay mixtures with a low clay content, in order to generate a stable basis for the following bench on the next higher level (spreader bench II in figure 1). This system has been in use in Hambach for decades but optimisation in terms of decreasing the sand use with respect to the amount of clay, is an ongoing process, because the margins are not very wide: the ratio clay to sand that can be stored (30%) compared to the amount that is available in the overburden (28%, corrected for bulking) provides us only with a 2% (volumetric) margin. This margin is in reality even smaller because the factor time needs to be considered: in Hambach surface mine there are 8 BWE and 6 spreaders (a 7th spreader operates in a nearby mine until mid 2009), one BWE is constantly working in the lignite, the others are dominantly removing overburden on a 24h, 7 to 7 basis. Each excavator can work up to 5 different slices in a face. Each slice can have a different material consistency and volume. Therefore 35 potential slices have to be distributed to 7 spreaders without ever halting the ongoing excavation and stacking process. But a spreader cannot handle every material at any time eg. only if a sand basin has been prepared, clay can be stacked. The logistics behind these processes must be optimised to guarantee the required lignite output, today and in the future. Moreover the system is very sensitive: if the guidelines for stacking the overburden (in terms of geometry and material consistency) are not followed exactly, either too much sand is utilised causing sand deficits on the other benches or too much clay is stored. In the latter case the risk of slope instability increases. Another important factor is the accuracy of the geological model (at the moment based on reconnaissance boreholes made several years in advance of the excavation). If the accuracy of the geological model can be increased this will be beneficial for the daily mass disposition which is largely based on this geological model. Therefore the machine operators in the mine, the staff and management in the office have to be supported to optimise the material disposition and stacking technology.

4 The digital mine

The support mentioned in the previous paragraph has been shaped by relying on IT-tools. This is in agreement with the results of an inquiry (NF 2000) in which IT were cited frequently as one of the most important advances shaping mining and quarrying practices, since they enable both management and staff to monitor, evaluate, and adjust operations in real time to maximise productivity and minimise cost.

Note that the introduction and diffusion of IT in mining has been slower than in other sectors, such as the petroleum and chemicals industries, in part because the mine environment presents unique and formidable challenges: mining equipment moves in a three-dimensional environment; the mine environment changes as mining proceeds; the mine environment is hostile to sensitive equipment; and the individual characteristics, and hence the requirements and restrictions for IT, of different mine sites vary widely (NF 2000).

Based on IT, the digital mine gives machine operators on the line as well as facility managers real-time and interactive 3D access to information needed for planning, managing, and optimising mine operations. Why 3D? Because three-dimensional graphical representation enables decision makers to quickly manipulate and understand complex spatial information that was formerly committed to paper (NF 2000). In addition on-line mass balances of the spreaders and the BWEs will run in the background and transmit mass balance information to other process optimisation tools.

With this target at aim, the digital mine can be defined as follows: One database in which all existing relevant spatial data (mine plans, position of wells, position of excavators and spreaders *etc.*) is collected, processed (automatic update of the digital terrain model by monitoring the stacking and excavation process on-line) and made available in real time (informative, interactive) to excavator and spreader operators in the mine and to mine planners, engineers and managers in the mine HQ (headquarters). The digital mine makes the complex dynamic mining processes transparent (eg. mine plans are sent down to the mine, whereas the on-line digital terrain model is sent back to the HQ) and guarantees data consistency, irrespective through which window the different users make use of and work with the digital mine (figure 2).

Set-up as described above, the digital mine collects all data and presents it in a three dimensional visualisation in the office world and outside for the operators of the large mining equipment. It uses the same data source, so all information is consistent. In this way the digital mine has an informative function. The way in which the information is presented is of course adapted to the working environment. Outdoors the use of mouse steering is not possible. Therefore the interaction with the data occurs through touch screens.

In the three dimensional working environment the data can be used to perform linear and three dimensional measurements of length and volume. Therefore the digital mine provides not only information of the on-line mine status but can be used interactively.

Another task for the digital mine consists in, by using it as a tool, digitising information previously only available in paper form, eg. the location and quality of in-mine gravel roads: gravel roads need to be constructed in the mine to allow for circulation of off road vehicles and other mining equipment. The location and quality of the roads are not mapped by the mine surveyors and the information about quality and location were only available in a single copy paper form. Towards the end of 2007 a tool was provided to draw this information in the three dimensional model of the mine by simple drag and drop functions. This information is saved into the database and can then be visualised by any user. In this way the digital mine is used actively to enter spatial data.

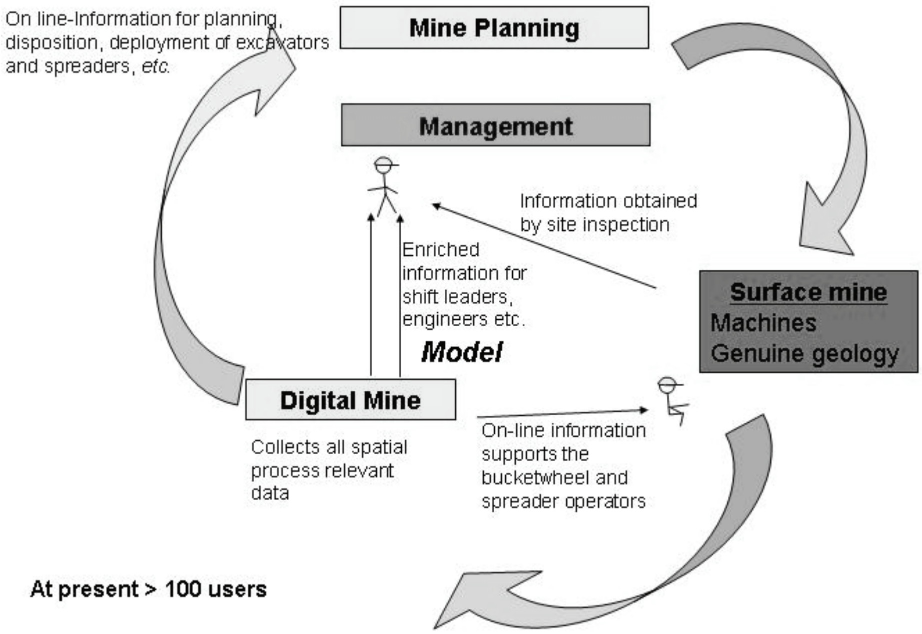

Figure 2 **Targets/tasks given by the management to the operating force in the mine can only be fulfilled if information about the machines and the geology is available. This information can be obtained through the digital mine. Other information must be obtained by site inspection.**

5 Input for the digital mine

Available spatial data

In a surface mine like Hambach surface mine, which has been in operation for nearly 30 years much information is already available and most of it has a spatial character. Characteristic for mining operations is that the information contained in this spatial data changes on a daily basis. Examples of such data are: mine operation plans, information about the dewatering wells (their position, flow rate *etc.*), information about the position of the main excavators (the BWE) and the spreaders, information about the position of the auxiliary equipment (bulldozers, dumpers, graders, hydraulic excavators *etc.*), information about the actual and future position of the conveyor belts, information about the in-mine roads (location and condition) and location of access ramps, information of the actual linkage between the different BWE and spreaders, as well as monthly information like digital terrain models obtained by aerial photography and photogrametric interpretation.

Some of this data is available in paper form, other is available digitally. The difficulty consists in transforming and exporting the data to the digital mine and making it available to the other users without need for additional manual operations.

New spatial data

As described above one of the targets of the digital mine is the automated update of the digital terrain model. For the excavators the method used to automate this process is simple and effective: By following the position of the bucket wheel excavator and by using inclinometers, the position of the bucketwheel itself is mapped. Where the bucketwheel has been, the volume is subtracted from the digital terrain model. Thereby the terrain model is constantly updated. For the spreaders the system requires more instrumentation: On the spreader side the mass movement is monitored by laserscanners mounted to the spreader boom. With the GPS system and inclinometers the position of the spread material is available real time in absolute coordinates updating the digital terrain model constantly. This short description shows that in order to obtain new spatial data additional sensors needed to be installed. GPS was introduced several years ago to measure the position of the bucket wheel excavators (Mr.Weber, RWE-Power). For this purpose a one-way (machine to office connection using radio waves) standard GPS-system - installed worldwide in bulldozers and hydraulic excavators - was used to determine the BWE’s position. This system has been upgraded since

October 2006 by a bidirectional system with a high availability and high reliability incorporating not only the BWEs but the spreaders too.

Note that the position of the excavators and spreaders, more exactly the position of the bucket wheel and the stacked material, is important whether this information is obtained by GPS at present or by any other means (eg. deploying several long range 3D laser scanners around the rim of the mine) in future is irrelevant.

All BWEs and spreaders had to be equipped with a glass fibre network, linking the systems on board to the LAN at the surface. At several positions on the machines there are hubs at which different sensors can be attached. An IP-address is allocated to all installed sensors. In this way the system is flexible and if changes in the arrangement or type or amount of sensors are necessary, these changes can be made without having to change the hard-wiring. In addition failure management can be performed by diagnosis or simple life checking (sending a ping) of the different sensors.

As mentioned above, for the on-line measurement of the stacking process, the most complicated task, the following suite of sensors is needed: 2 GPS-antenna and a microcomputer, several inclinometers, two 2D-laserscanners. In addition to this, one industrial PC and one touch screen monitor for each operator cabin is needed.

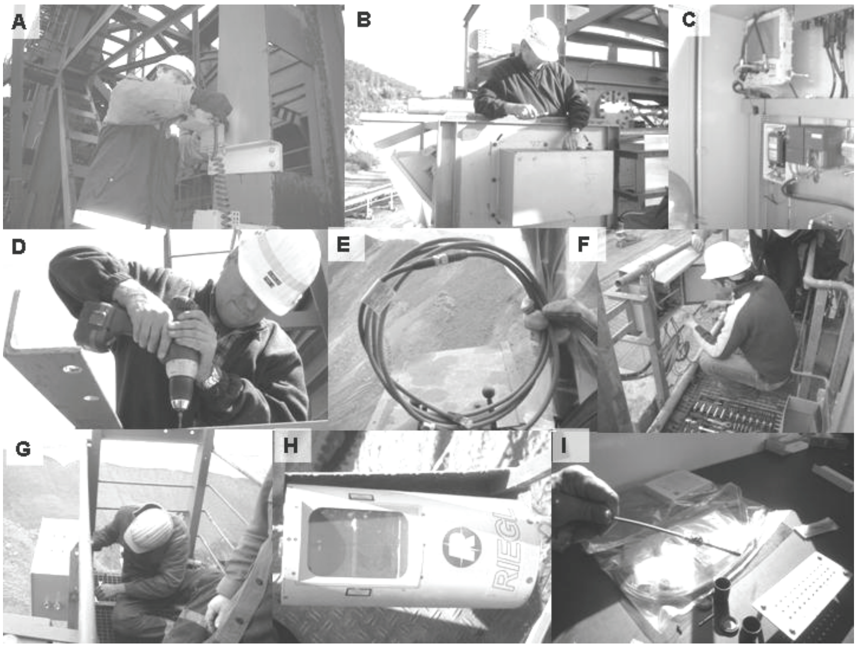

Figure 3 **Different additional sensors installed to monitor the stacking process: A) Inclinometers, B) Scanner cover C) Standard GPS system D) New mounts for scanners E) Hard wiring F) + G) Connection of the scanners H) 2D Laserscanner I) Fibre optic connection made in situ.**

These additional sensors must be mounted without interfering with the production in a 24h 7 to 7 working environment. A standstill for sensor upgrading is not possible. However every machine will be subjected to a regular minor maintenance check every 5 weeks and to major maintenance checks at much larger time intervals. These maintenance periods provide time windows which can be used to install the hardware on the machines and to have the hard-wire installed for the local network.

Because these tools need to be function on a 24h - 7 to 7 basis, all equipment has to be selected and installed in such a way that failure diagnoses is fast and simple. Simple means that failure codes are displayed not as a code but in regular textural form. Other malfunctions, which origin could only be identified by the specialist data mining databases, have been analysed and software has been written in such a way that the interpretation is performed by this software. The failure source is described in regular textural form and can be accessed by the machine operators who can inform the different maintenance crews.

6 The digital mine at its current state

At present the operators, shift leaders, planners, surveyors, project engineers and the management are supported by the digital mine through visualisation tools. These tools are described in this section starting with the tools for the shift leaders of the BWEs, followed by the applications for the shift leaders of the spreaders, the shift leaders of the auxiliary equipment, the operators of the BWEs and the operators of the spreaders

- Shift leaders BWE: The mine operations continue at a 24h basis. With 8h shifts there is a change of shift three times a day. During this change of shifts the shift leader of the current shift has about 30 minutes time to explain the current state of the mine eg. the position of each BWE, the location of difficult overburden, etc. to his successor for the next 8h. The desk visualisation showing all spatial information of the BWE shown in figure 4 and figure 5 has been found particularly useful. This desk information does not only show information but it can be used to measure distances between any objects, heights and volumes.

Figure 4 Change of shifts using the desk visualisation of the digital mine as s tool.

- Shift leaders spreaders: With a similar desk tool the shift leader of the spreaders can obtain information about the position of the spreaders and has access to an automatic update of the digital terrain model because the stacking process is monitored on-line and the scanned surface is shown as well (figure 6). The information of the actual surface supports the disposition of the overburden on the different spreader benches enormously, because now it is known whether it is still possible to deposit clay into basins etc.

- Shift leaders auxiliary equipment: To manage the auxiliary fleet (120 vehicles) efficiently, the position of these vehicles, the position of excavators and spreaders and the digital terrain model at present must be available. Therefore these vehicles have been equipped with low cost GPS sensors. This information can be accessed through the desk application shown in figure 7. This desk application is used to map the position of in-mine gravel roads as well.

- Operator of the BWEs: In figure 8 the operator's cabin of the BWE is shown. Via this visualisation the operator has access to the information contained in the digital mine. The same information as discussed above can be displayed (figure 5). However some information is deliberately omitted (eg. the position of the auxiliary equipment) and some data is shown more pronounced like the mine plan (transmitted automatically from the mine planning department). In detail the operator receives information about the position of the bucket wheel relative to this mine-plan. A light bar incorporated into the touch screen shows when the excavation process should stop to avoid over- or undercutting. The modelling of the cutting process is calculated on board of the machine, transmitted to the digital mine and is made available for all other applications.

- Operator of the spreader: In the visualisation for the operators of the spreaders, various sections through the mine plan and the actual spread surface can be selected (figure 9). In this way the operator has immediate information about the geometry he should follow in order to deposit the material correctly according to the mine plan. The scanned surface, recalculated into a raster surface on board, is part of the digital mine and is, as such, available to all other users and other programmes like future disposition programmes which are currently developed.

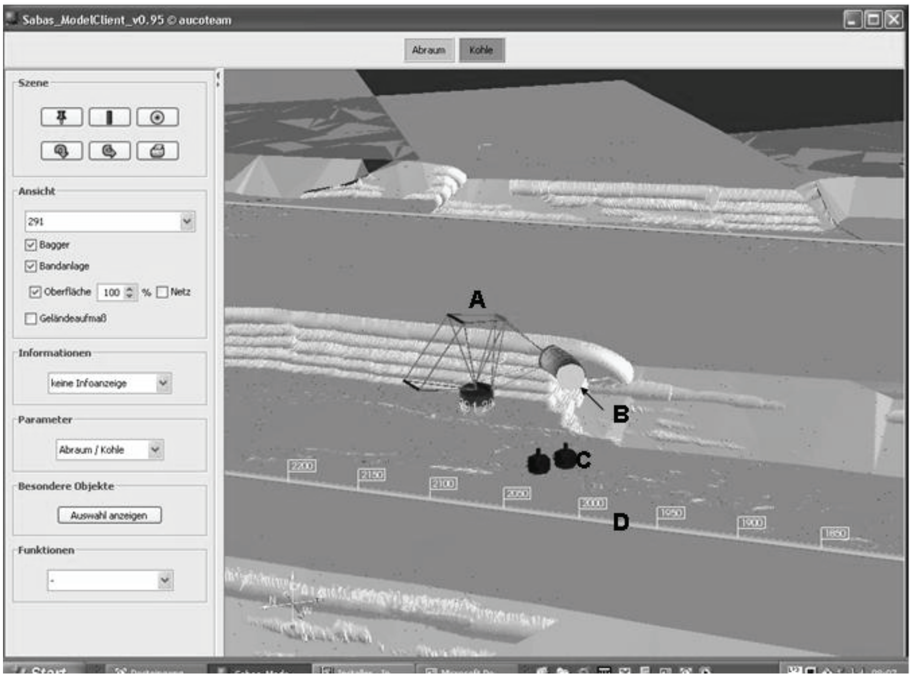

Figure 5 **Screenshot of the desk visualisation of the digital mine showing the BWE (A), the position of the BWE along the conveyor belt (D), the slice the BWE is excavating (B) and the position of two pieces of auxiliary equipment (C). In addition to this information the position of wells, the geology from the geological model, the mine plan etc. can be visualised.**

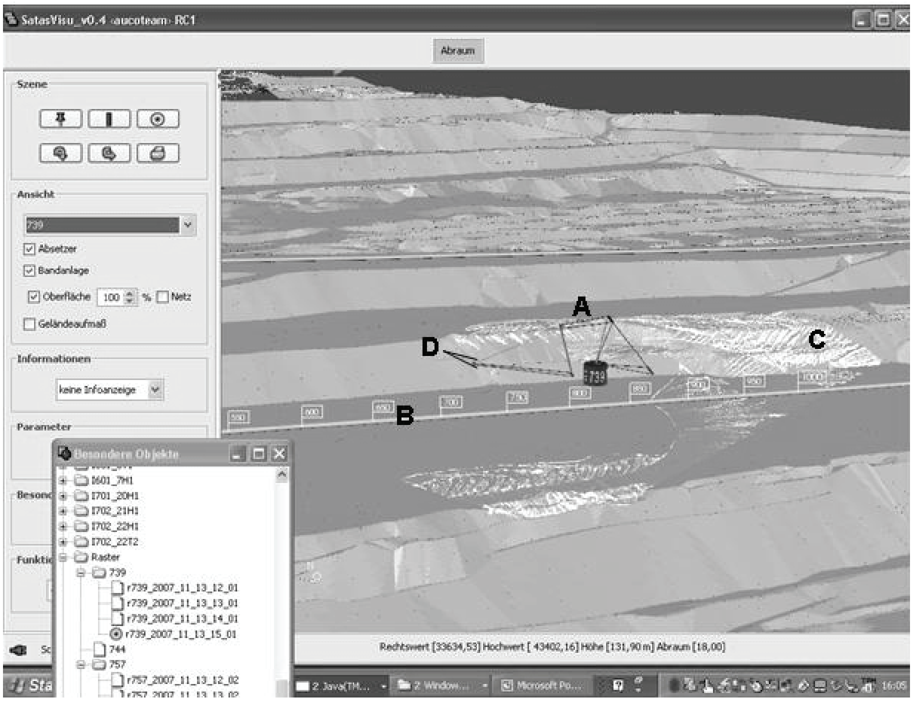

Figure 6 **Screenshot of the 3D desk visualisation of the spreaders. Like for the BWE, the conveyor belt is shown (B). The actual position of the spreader is shown at A. The actual surface is depicted in light grey at C. The actual surface has been obtained by scanning using the scanners positioned at D.**

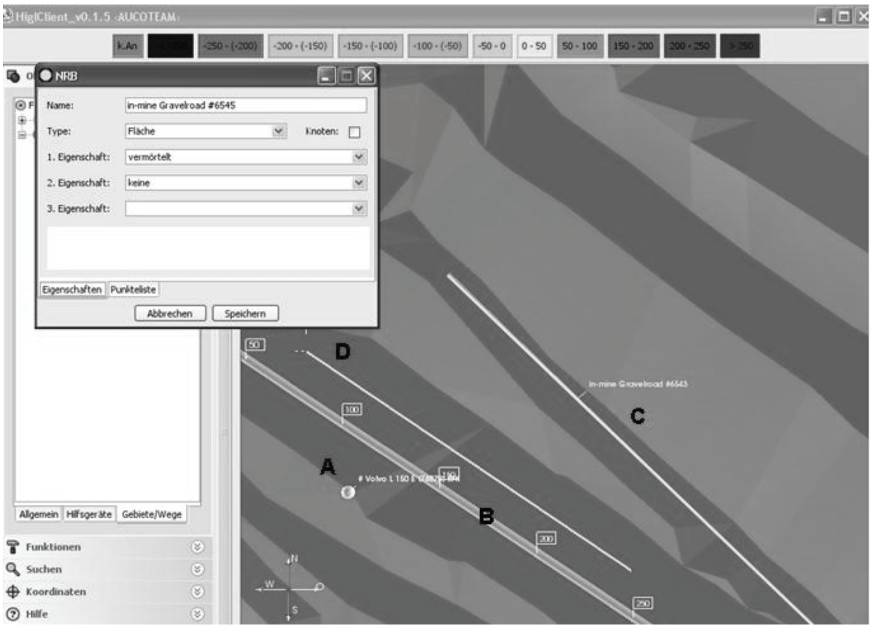

Figure 7 **This image shows the desk application to manage the auxiliary equipment of the mine. There are 120 machines (bulldozers, D9-pipelayers, dumpers, graders, vehicles of the fire department etc.). All these vehicles are equipped with GPS. The logistics of the deployment of all these machines is supported by this desk application. In this example the position of a Volvo L150 is shown at A. At B the conveyor belt is shown. A in-mine gravel road was mapped at C, and by a simple manipulation with the mouse another in-mine road is currently plotted in this three dimensional environment at D.**

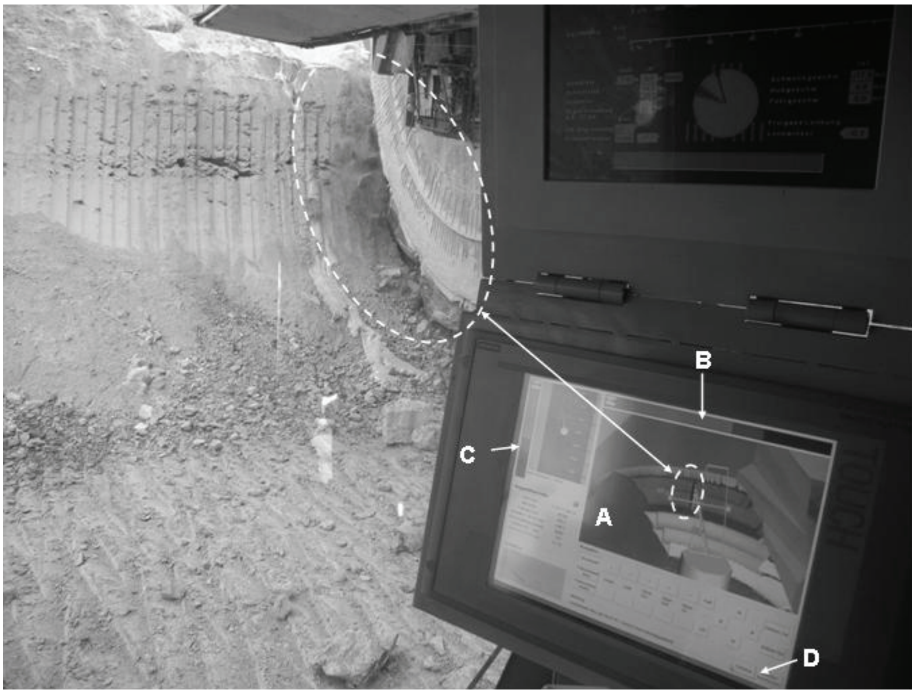

Figure 8 **Although the content of the information from the digital mine for the desk application and the BWE's operator is identical, it is displayed differently: The mine plans (A) have a dominant position in the display. The distance from the bucket wheel to the mine plan is displayed at B and C: This is a support for the operator to keep to the mine plan. At D the service page with additional information (name and position of the current partner spreader, failure diagnosis screen) can be accessed.**

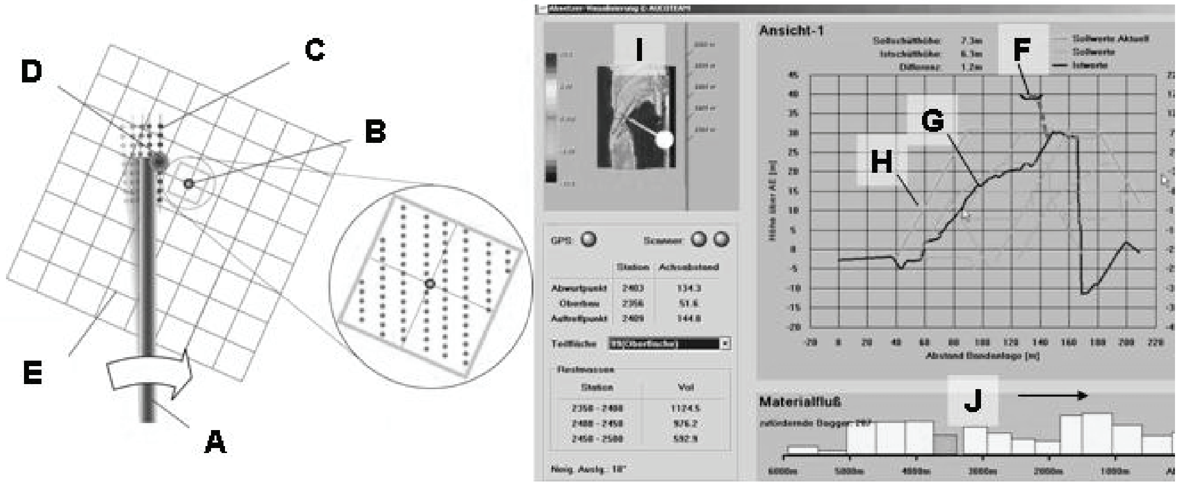

Figure 9 **To be able to scan the surface of the stacked material, laserscanners (D) have been attached to the slewing boom (A). Due to the slewing operation the 2D scanned path (C) of the scanners is used to generate a 3D raster surface (B, E). This raster surface is displayed in the operator's cabin (G) together with the mine plan (H). In this way the operator can guide the boom (F) and use the display to spread the material according to the mine plan. A general overview of the spreader's position with respect to the conveyor belt is available at I. At J the operator can obtain information about his partner BWE and the amount and type of material on the way to his spreader.**

7 The digital mine at present and outlook

From October 2006 to October 2007 three spreaders were equipped with scanner and GPS technology and the visualisation tools. In this same period a fourth spreader was nearly completed. The installation of the hardware commenced on two other spreaders and will be completed in 2008. A 7th spreader, currently recultivating a mined out site near to Hambach surface mine, will be upgraded in 2009. Two out of 8 BWE have been upgraded in 2007 with the new visualisation and the bidirectional connection to the digital mine. The other 6 BWEs will be upgraded in 2008. Raster surfaces have been made available through the digital mine to all users. Especially for the overburden logistics this is an important benefit. A disposition tool is currently in development. This tool will be fed with the information deduced from the raster surfaces and will perform mass calculation from 2008 onwards. The mine planning departments have issued the wish to plan directly in three dimensions in the applications shown in figures 5 and 6. The programming of an appropriate tool was scheduled in May 2007 for 2008. The first step towards a genuine 3D planning tool in these applications (Figure 7) has resulted in the tool created to map the in-mine roads. This tool was realised in 2007. Because the mass movement by auxiliary equipment is not tracked (only low cost GPS is used), a tool is currently under development to incorporate this mass movement (eg. creation of an access ramp) by adding a simple interface into the programme shown in figure 7 allowing the user to choose from pre-defined volume elements. As discussed in section 3 an increased accuracy of the geological model would be beneficial for overburden disposition. A method that can be used to increase the knowledge of the geology is to ask the support of the BWE operators or spreader operators. The BWE-operators are working in the geology all year round and have a lot of experience therefore their input is valuable. The availability of the touch screens permits a user friendly input of geological material descriptions. The manual input can be reduced to a minimum because only deviations from the actual geology with respect to the geological model need to be registered. This information is stored in the digital mine and is available through interpolation - taking the dip and discontinuities into account - for excavation of the adjacent stretch of overburden.

Acknowledgements

The installation of the sensors, IPC and hard-wiring was made possible by the department of Mr. W. Stock, and Mr. Wegner, Mr. Hardt, Mr. Assenmacher , Mr. Peters and Mr. Bräuer. Mr. Herbst, Mr. Wiedelmann and Mr. Koenigs (Aucoteam Berlin) have written the software. My predecessor as project leader Mr. Weber started the project with much effort and enthusiasm.

References

NF (2000) New forces at Work in Mining: Industry Views of Critical Technologies. 2000. The RAND Science and Technology Policy Institute, Arlington, VA

Pohl, W. (1992) Lagerstättenlehre. 4th Edition. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Walter, R. (1995) Geologie von Mitteleuropa. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart

ENB. (2005) Origin of the Lower Rhenish Lignite. Brochure RWE-Power. (in German)

Schmitz, R.M., (2007) Laserscanning in Mining: Developments in Hambach Surface Mine. 11th Congress of the International Society for Rock Mechanics, Lisbon (Portugal) (Proceedings on CD Special Sessions)

Schmitz, R.M., Kübeler, U. (2007) Laserscanning in Hambach Surface Mine: Basis for the digital mine. German-Rusian forum for surveying with laserscanners in mining. Bochum (Germany). (Proceedings on CD)