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Spatial information management from multidisciplinary data

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For several years now South Africa's major mining groups have been accumulating vast amounts of electronic data. This is the natural consequence of the use of mining technical systems (MTS) in various mineral resource management (MRM) initiatives.

In the course of the evolution of MRM much has been accomplished in terms of integration due to process thinking and information management practice.

The next step is the introduction of a spatial database enabling subsequent visual integration whereby combinations of multiple forms of geological, planning, safety, financial and production data can be brought together in a unified picture.

Referencing GMSI's mineRP Framework and the Open Geospatial Consortium (OGC) compliant database (spatialDB), the paper and presentation will focus on current progress and practical use for a visual analysis toolset.

Keywords: mineral resource management solutions, enterprise mining solutions evolution, process standardization, mining business reference model, spatial information management, spatialDB, spatialDash.

Introduction

As mentioned in the abstract, South Africa's major mining groups have been accumulating vast amounts of mining related electronic data as the natural consequence of the use of mining technical systems (MTS) in various mineral resource management (MRM) initiatives.

On different mines and in different mining houses the accumulated data reflect approaches to information management across the spectrum of decentralized, single user desktop initiatives to centralized enterprise initiatives. The scale and scope of IT implementation is as varied as the client base. Approaches range from a single discipline user base to corporate information management structures involving multidisciplinary reporting and in particular coordinated planning and financial information. In between, we have the comprehensive shaft based MRM department or regional MRM structures serving multiple, geographically bound operations.

The decision for centralized or decentralized information management sometimes reflects the constraints of geographic spread, relative infrastructural isolation and limitations of IT technology at the time of decision making. Given the constraints as may still exist, it is interesting to note the transition from almost universal pencil and paper based planning and control systems to almost universal IT based systems has taken less than 15 years.

As the amount of technical data accumulated on each mine, so did the requirement to put the data to good use, specifically given its relevance to ongoing strategic optimization efforts and management decision making in a world of volatile commodity prices.

In parallel with the growth of localized information stores at operational level, more and more larger mining houses found themselves needing rapid access to those local information stores from head office levels. This was needed in order to coordinate at a corporate level, the diverse plans and production profiles from operations and new projects.

The organizational requirement for information collection and reporting as a tool in strategic and tactical decision making placed higher demands on operational efficiencies. This caused waves of process optimisation initiatives, radically changing the way interdisciplinary data was shared and reused.

Whereas this situation is certainly not unique to mining technical solutions, there is a common denominator which emerged for the multidisciplinary data used across the mining value chain: its spatial reference.

Most commercial enterprise resource planning solutions use things like cost- and profit centres as reference against which to express variables such as expenditure, resource requirements and other operational metrics. Mining technical solutions are more concerned with identifying the exact physical location of a given resource in the process from location through extraction to the eventual beneficiation and sale of product. In order to ensure optimal planning and execution, mining technical systems have to communicate with one another using spatial location as the common reference.

This means that questions posed in this domain are more often than not answered around a plan or layout of the actual mine, and not only as tables, reports or bookkeeping debits and credits. Solutions to accurately visualize spatial information in a way that would make sense even to non-technical stakeholders became critical components in the arsenal of the mineral resource manager.

The current situation then is one where an extremely high premium is put on the availability and usability of mining technical information across the total mining value chain, even into the highest levels of the organisation. This paper

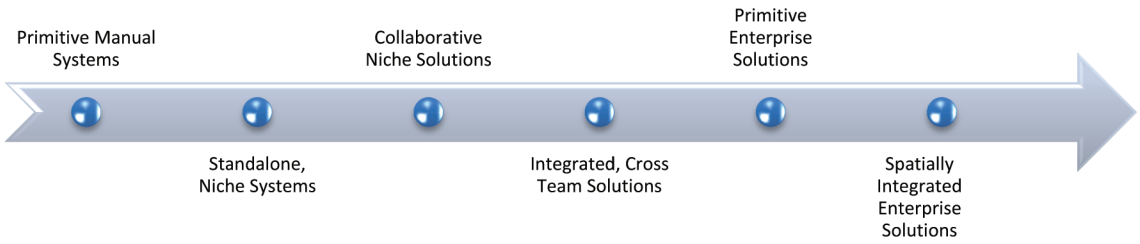

Figure 1. Evolutionary development of mining technical solutions

will discuss some of the major drivers and outcomes in the mining industry's efforts to achieve seamless horizontal and vertical flow of mining technical information.

The evolution of spatial mining technical solutions

With the overabundance diverse mining technical applications used at mines, also came very large amounts of (often critical) business data saved on individual machines or local area networks at best.

Across different technical mining disciplines, data capture patterns vary depending on factors such as size or age of mine, mineral content and mining method. Taking a snapshot view across a sample of different platinum mines, the following statistics may be of interest.

- No. of sample sections (a HW to FW section consisting of many samples) vary from 43 on a new mine to an accumulated total of ± 50 000 on a large mine over many years;
- No. of samples (the basis for lots of other work) from 400 to 500 000
- No. of stope observations from 1100 to 200 000
- No. of survey measurements (discrete monthly measurement of mining excavations varying with both size and age of mine) from 250 to 220 000
- No. of mine design items (this represents a volume of planning work consisting of planned underground excavations captured by a planner, which may or may not be scheduled / used) from 750 000 to 15 500 000
- No. of schedule items (represents business value as discrete period based schedule segments of mine design elements) from 79 000 to 5 000 000.

Mine design and schedule items will also indicate the future size of a mine. For example, a young mine with intention of becoming a big mine in the future may well have more mine design and schedule elements than an existing, smaller and older mine.

As time progressed, the mining industry went through a distinct process of evolution of mining technical solutions, as shown in Figure 1.

First generation: primitive manual systems

As can be imagined, most mining organizations started off with manually operated, often paper based solutions where the process from planning through execution and review is strictly sequential, and opportunities for mid-process adjustment of approach, underlying parameters and schedule are few and far between.

Primitive systems are not necessarily primitive in the sense they are extinct, or even completely inappropriate. They are simply primitive seen from the perspective of spatially integrated enterprise solutions, but may still be the best approach for a small-scale, small budget mining operation where the ability exists to verbally share information and adjust execution accordingly. See Figure 2 and Table I.

Second generation: standalone niche solutions

Second generation mining solutions focussed exclusively on delivering a set of niche function points to a specific business discipline. Whether it was delivering a block modelling solution to the geologist, or a pegs database to the survey department, the focus was basically around creating a collection of productivity tools to help a given individual or team in their task.

The main characteristic of second generation solutions then, was that they focused on delivering (sometimes very complex) functions within a single problem domain. These systems were sometimes hardware specific and were often connected directly to peripheral devices which aided in their aim to optimize a specific function. See Figure 3 and Table II.

Third generation: collaborative niche solutions

Third generation solutions were essentially no different from those of the second generation, but simply utilized the development of networking technology to allow multiple system users within the same domain to collaborate on projects within that domain. Primitive workflow engines started to develop, enabling further optimization of tasks within a department or function.

Reporting from third and second generation systems was still very much focused on the KPIs generated within the thin area supported by the given system/solution. See Figure 4 and Table III.

Fourth generation: integrated, cross team solutions

Fourth generation tools saw the first real progress towards

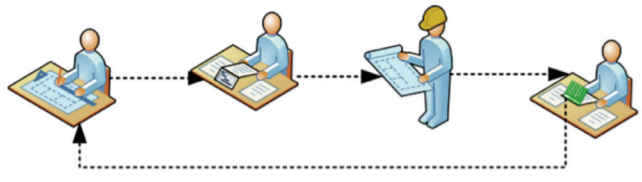

Figure 2. Primitive manual systems

Table I
Key features of Primitive Manual Systems

Key features
Mainly paper based
Very sequential

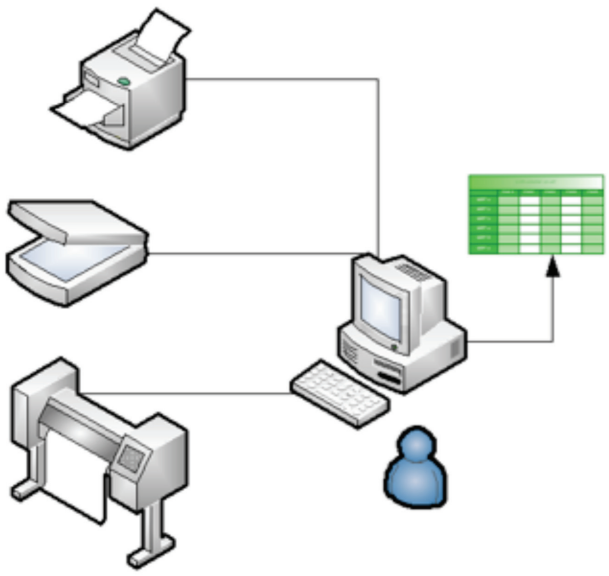

Figure 3. Second generation mining solutions

Table II
Key features of second generation mining solutions

Key features
Focus on single domain productivity
Single domain reporting

enterprise integration being made. Not only was information being shared within disciplines, but systematic support of cross-discipline information sharing started to develop. See Figure 5 and Table IV.

Mining managers started expecting of systems with related information to be aware of their peers, and even started to create cross-discipline, multiple KPI reports used at higher levels of the organization. It was, however, still true that in the majority of cases, intense human intervention was required to generate cross-discipline reports.

Fifth generation: primitive enterprise solutions

With the emergence of robust enterprise resource planning (ERP) systems for the commercial and supporting functions of mining organizations, an awareness of the lack of integrated production and financial/commercial information started to emerge.

While the immediate problem of sharing information horizontally across the mining value chain seemed to be at least somewhat resolved, focus grew on relating operational KPIs more directly to financial and strategic measurables.

Many traditionally non-mining technology providers started to provide systems and tools to allow corporate head offices to roll operational information up through semi-intelligent extract, transform, load (ETL) processes, and deployed enterprise data warehouses as a means of persisting transformed, standardized and denormalized information at a head office level. See Figure 6.

This new approach originally promised to deliver vertical integration of what was assumed to be horizontally integrated information, yet it did not take long for the industry to realise that core operational data sets and supporting organizational datasets did not share the same common denominators. Where financial and other supporting data-sets typically centred around dimensions such as organization structures and cost codes, operational information was much more concerned with the exact location in space to which any given slice of data applied. See Figure 7.

Getting information from the planning rooms at operational level to the executive boardrooms still proved to be a very elusive goal.

Sixth generation: spatially integrated enterprise mining solutions

Latest developments in the evolution of the mining technical solutions world are all headed towards the same goal: enabling enterprisewide collection, reporting and visualization of information from the total spectrum of

Table III
Key features of collaborative niche solutions

Key features
Focus on single domain productivity
Single domain reporting
Single team sharing and workflow

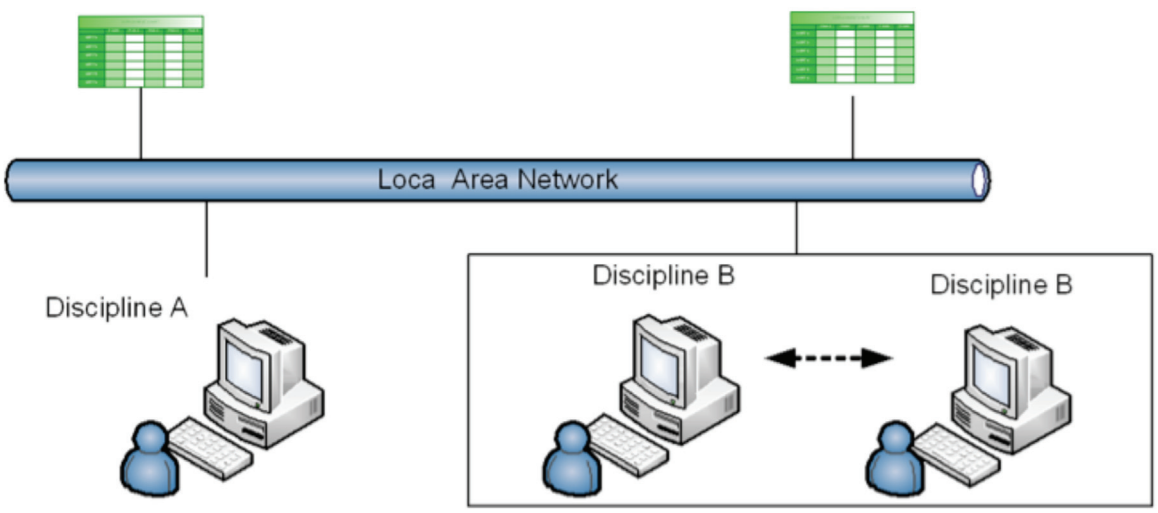

Figure 4. Collaboration tools

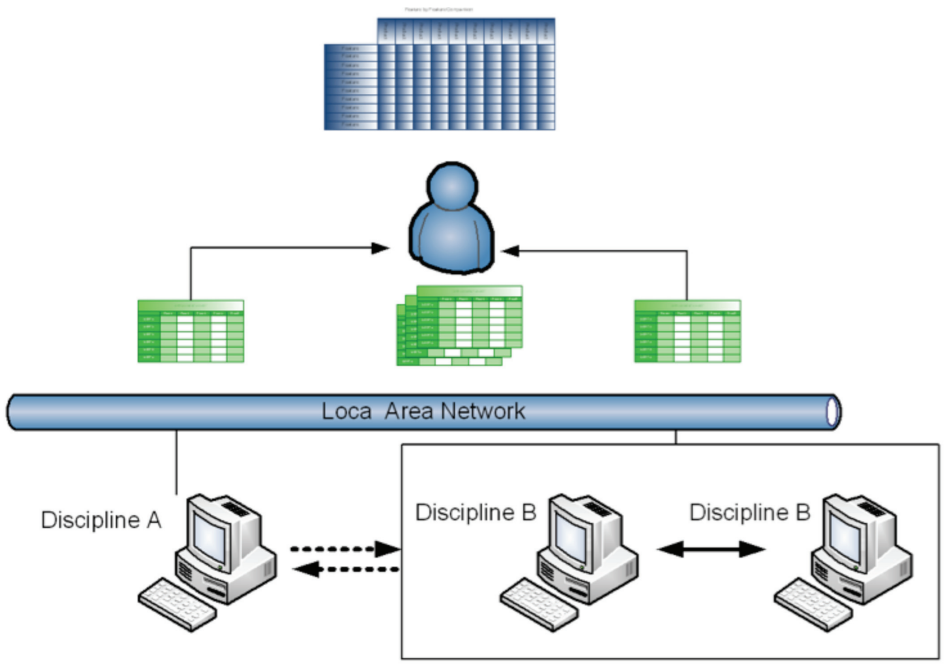

Figure 5. Integrated solutions

Table IV
Key features of collaborative niche solutions

Key features
Peer aware niche products emerge
Cross-domain reporting
Intensive human intervention required to marry domains

organizational data stores, including both business information and core operational information.

Technology strategists and business leaders globally, agree the visual presentation of analytics will become increasingly pervasive as we move into the future, because this approach enables business to see patterns that might otherwise remain hidden. See Figure 8.

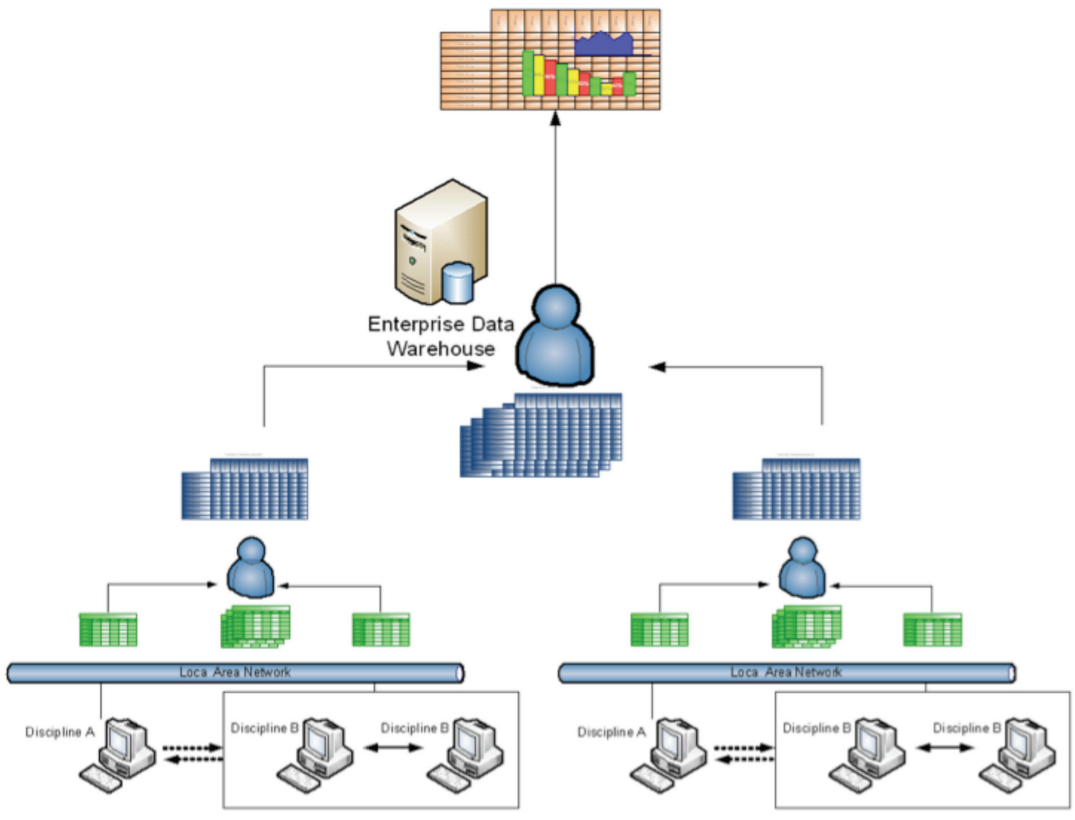

Figure 6. Enterprise data warehouses

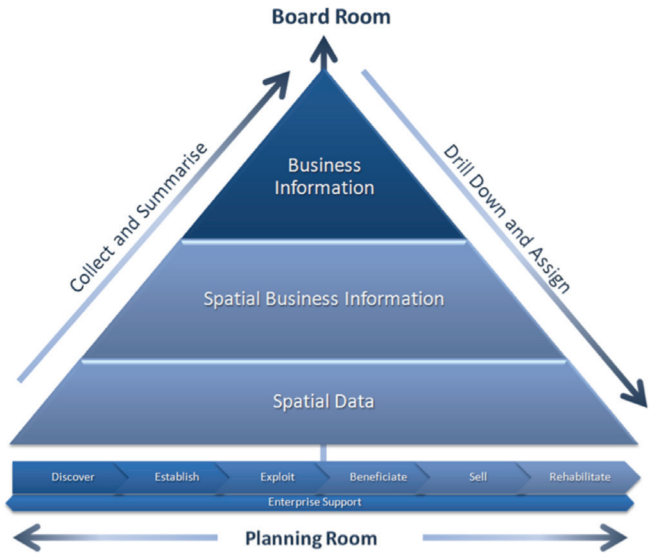

Figure 7. Changeover from corporate to operational data

Challenges to overcome in this domain include the standardization of terminology and other 'master data' items, including naming conventions, calendars, organization structures, etc. Furthermore, as miners expect to be able to visualize information from disparate sources on a single canvas, the ability to translate proprietary file and database structures of possibly many different solutions in place at different operations becomes a nonnegotiable requirement.

Some mining technology vendors attempt to simplify this landscape by simply storing and extracting data-sets (specifically design and model files) as intact objects in a central data store. Enterprise specialists, however, agree there will be no real horizontal and vertical spatial enterprise integration unless systems are able to discover, translate and eventually consume related business information. This information may be stored at any location in the logical organization, with access not dependent on its physical locality.

The unprecedented, insatiable need for more (and more timely) information has further increased the need to standardize the terminology and conventions across the mining industry. Not only is it necessary to be able to use single, industry standard terms for mining processes and activities across all regions, mining methods and minerals, but it is also essential that actual data elements are stored in an openly accessible, globally recognized standard. Only then will we achieve seamless exchange of spatial information throughout the organization.

Mining process standardization

In the course of the evolution of MRM, much has been accomplished in terms of integration and standardization due to process thinking and information management practice.

The South African mining industry in particular has been well served for over 10 years by various mining value chain definition initiatives. What they share is an approach to understanding the mining business as a process.

From 1999 onwards, the mining industry in the South African context at least, has had the benefit of continuous focus on definition of the mining business as a process. The advantage of understanding mining as a process is firstly as a bridge. On one side we have the mine based employees, each understanding the business from the perspective of their functional role and on the other, software development teams understanding any business as data points. The last thing you want is these two parties holding unsupervised conversations. Scope creep, misunderstanding and never ending code development is the natural result.

Importantly from an IT perspective, any software offering

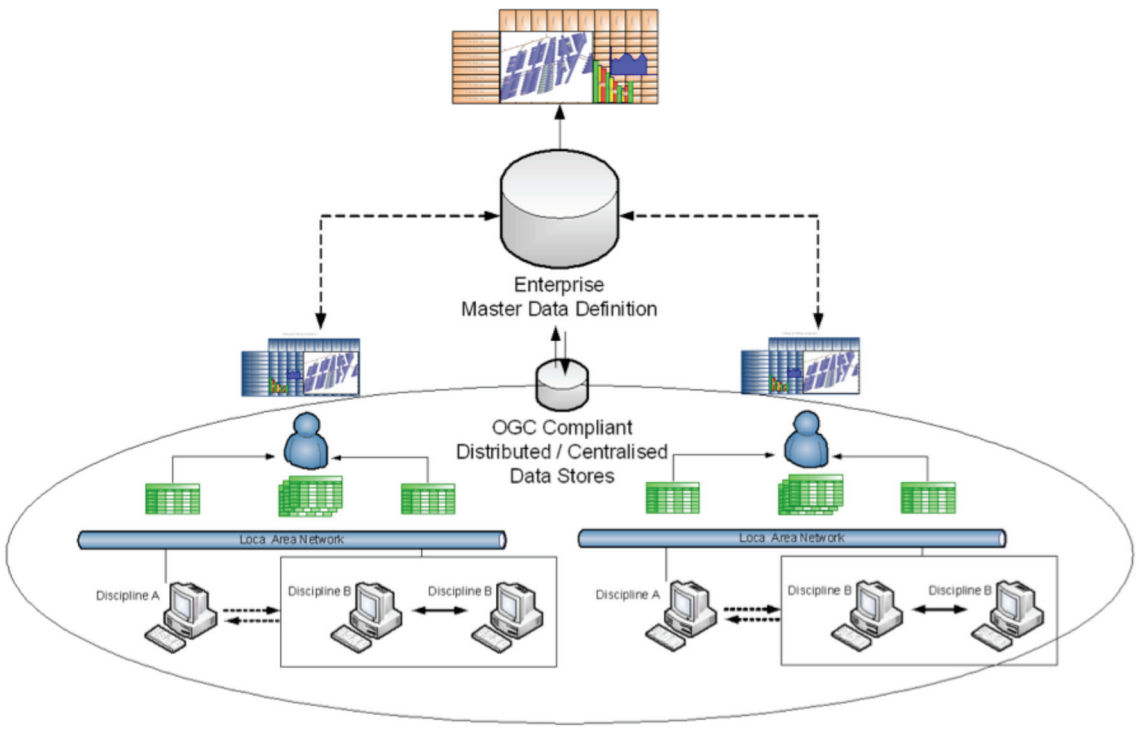

Figure 8. Spatially integrated enterprise mining solutions

Table V
The mining value chain functional transformations

Transformation	Definition	Input	Output
Locate	The determination of the presence of a deposit	Suspected mineral resource deposit	Mineral resource estimate
Valuate	The determination of the . profitability of a project	Mineral resource estimate	Bankable feasibility (Go – No Go decision)
Establish	The execution of the mine plan	Bankable feasibility (Go – No Go decision)	Exposed mineral resource
Mine	The removal of mineral resources	Exposed mineral resource	Contained and classified broken rock
Transport	The movement of classified broken rock from source to destination	Contained and classified broken rock	Stockpiled tonnage at grade
Beneficiate	The extraction of saleable products and the disposal of residue	Stockpiled tonnage at grade	Saleable products
Market	The maximization of profit	Saleable products	Revenue and profit
Divest	The curtailment of operations	Revenue and profit	New economic circumstances

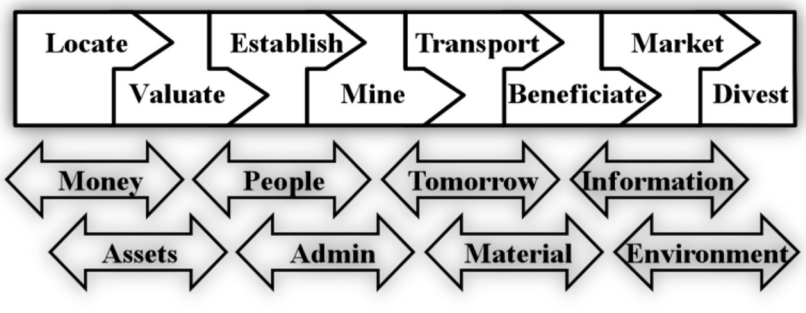

Figure 9. The mining value chain and support processes

has a process locked away inside it. The implication is, if this process does not match the reality on site, it is the wrong IT tool. Understanding the business as a process provides a common base from which to hold diverse conversations. Thus, having a well defined process map at an appropriate level of detail provides a useful tool for understanding many aspects and views of the same business. Once a suitable IT strategy is developed, the process map readily lends itself to activities such as forming a basis for allocating roles and responsibilities, matching users and IT tools, implementing IT tools and managing information flow across the business.

GMSI participated in a formal mining value chain definition exercise as recorded in the March/April 2001 SAIMM *Journal*. See Table V.

With this as a foundation we have engaged with multiple clients and user groups and continued to develop the scope of definition to include support processes covering non-core but critical business information requirements. See Figure 9.

More recently, existing separate examples of process definitions have been supplanted by a global initiative under the auspices of the Open Group. See Figure 10.

The Open Group is a vendor-neutral and technology-neutral consortium, whose vision of 'Boundaryless Information Flow™' aims to enable access to integrated information, within and among enterprises, based on open standards and global interoperability. The Open Group enables an independent platform for collaboration, removing issues related to anti-competitive behaviour and claims related to intellectual property.

One example of the Open Group's forums is the exploration, mining, metals and minerals vertical (EMMMv) forum. Their objective is amongst other things, to realize sustainable business value through collaboration around a common operating model enabling mining companies to better manage their business-IT investment and supporting vendors in their delivery of technical and business solutions to the industry.

The EMMMv Forum was established formally under the auspices of The Open Group in 2008. Having its Vision, Charter and product portfolio defined promptly identified its priority as construction of a business reference model. Work proceeded as an iterative approach based on participation from members and other contributions from mining companies and vendor representatives in South Africa, Australia, and England.

The exploration and mining (EM) business reference model including a list of terms and definitions is the first active deliverable of the EMMMv forum.

Practical applications of enterprise spatial information

The introduction of spatial databases means the enabling of subsequent visual integration whereby combinations of multiple forms of geological, planning, safety, financial and production data can be brought together in a unified picture.

Referencing GMSI's mineRP Framework and the Open Geospatial Consortium (OGC) compliant database (spatialDB) we will now turn to current progress and practical use for a visual analysis toolset.

The underlying basis of GMSI's mineRP Framework initiative is an OGC compliant database called spatialDB. Storing or mapping to multidisciplinary information in a common format it becomes possible to provide answers to complex management questions in the form of a

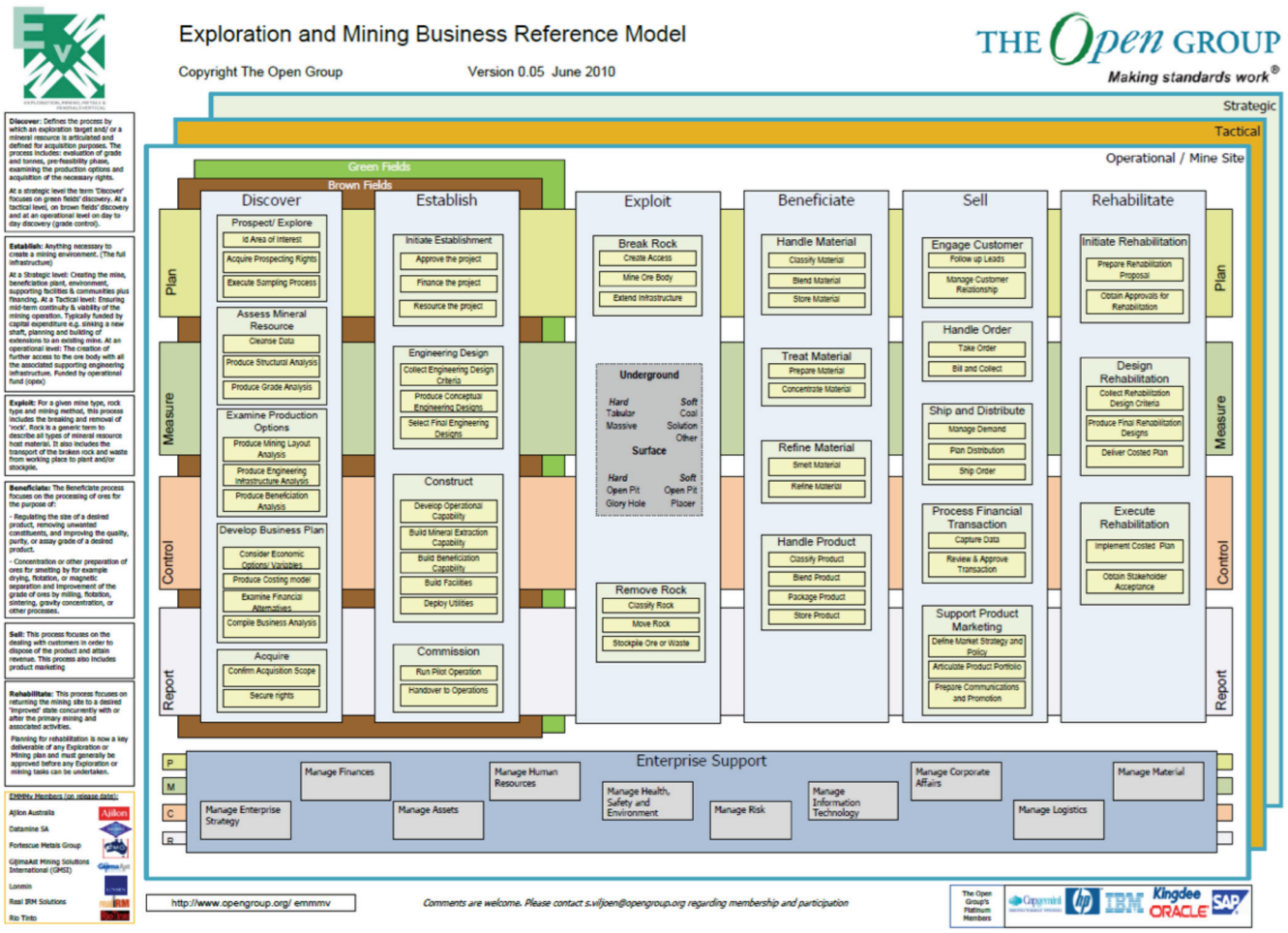

Figure 10. Exploration and mining business reference model

recognizable picture. The picture has the mine layout as the backdrop, so the presentation of information is immediately familiar to those asking the complex questions. See Figure 11.

To sustain this new initiative in information management GMSI has enabled spatial data mining. Data mining is the process of systematic conversion of raw data into enriched information through analysis, processing and interpretation. The outcome is rendered in a spatially relevant format and provides specific/factual insight aimed at resolving or optimizing identified operational challenges. It enables pictorial representation of casual and causal effects.

There is a two stage process in delivering spatially representative information:

- Data analysis and interpretation: data analysis involves working to uncover patterns and trends in data sets, whereas data interpretation involves explaining those patterns and trends
- Spatial representation of data: GMSI renders these insights in a graphical/electronic format that is 'yet simple', but provides the 'wow factor' impact for such information.

The application of these new spatial tools combined with the necessary skills is directed at assisting mining management who find themselves engulfed in operational challenges. This is usually exacerbated by reduced staffing levels and on-mine capacity. Consequently, there is often no inclination to look more closely at existing data, so ongoing tactical responses may be misdirected and inappropriate.

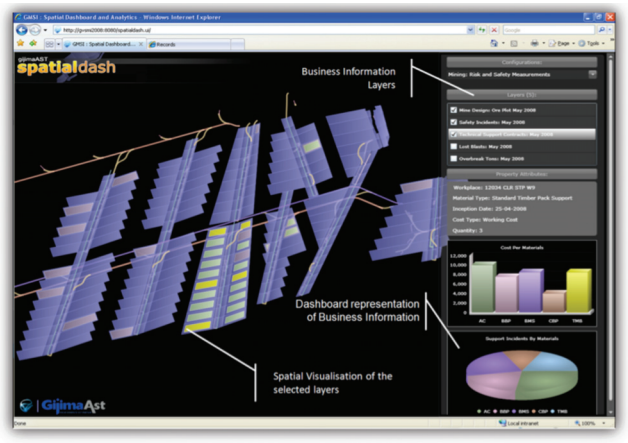

Figure 11. Visualising integrated enterprise information using GMSI spatialDash

Whereas the range of real world applications of spatially integrated enterprise mining views is an open set, some readily usable combinations are:

- Productivity and face availability conflicts
- Productivity with crew availability and composition
- Productivity/stores supplies/costs by mining area
- Productivity/utilities (air and water)
- Safety: FOGs vs. geology and support coverage
- Safety: lead/lags of panel headings

- Spatial compliance (planned not mined/mined not planned)
- Lost blast analysis vs. geology
- Dilution reporting and costing consequences
- Geology mapping coverage
- Planning data from various disciplines—survey, rock eng, ventilation, etc.
- Legal compliance: survey layouts
- MCF investigations.

Conclusion

South African mining house commitment to mineral resource management and the use of mining technical systems has laid a significant base of best practice for the management of such information at an enterprise level.

Standardized process thinking has enabled the creation of widely used, practical models and business practice to facilitate organization integration and overcome traditional barriers to information sharing and collaboration.

More importantly, in recent years, GMSI has developed a mineRP framework based on a spatial database (GMSI spatialDB and spatialDash) to breach discipline specific technological barriers and enable visual integration of mining and business information.

Both our process knowledge and technology, combined with the enterprise experience from South Africa's mining environment are being exported to other parts of the mining world.

Perhaps the most fundamentally useful aspect is all about treating the orebody as a business asset and enabling the ability to provide auditable visibility on management information.

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In the last 33 years worked extensively in SA gold and platinum mining for Gold Fields.
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Since then worked on introducing various IT technologies into the local mining scene and more recently on introducing communications and tracking technologies from Australia onto Africa.
Happily married to Waveney and due to be a grandfather in a few months' time.