



The Digital Mine

– Concept and perspectives –

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1. Introduction

The term “Digital Mine” is not just a marketing slogan of PSI Production but is derived from the initiatives, reaching back into the early 2000s called “Digital Factory”. PSI Production was involved in that work.

Some important background information to understand the terms like “Digital Mine, Digital Factory, Digital Production” is given in this introduction.

The initiative “Digital Factory” had its roots in the simulation of plants (buildings) inclusive the machinery and equipment as well as the simulation of the production processes running on that machinery. The German engineering association VDI (Verein Deutscher Ingenieure) published an engineering guideline describing the main features of tools and methods supporting the planning and design phase of factories.

Digital factory – Fundamentals (VDI 4499 Blatt 1)

One of the main benefits of this initiative were

- Consequent introduction of standards (engineering methods, tools)
- Continuous and consistent data management
- Consider a production as an entity (holistic production)

From 2007 on those beneficial aspects were more and more considered also in the context of the operation of a factory or – more neutral – a production site. In early 2010 VDI published a draft guideline called

Digital factory – Operations (VDI 4499 Blatt 2)

The “Digital Factory – Operation” is considered as a network of models, methods and tools supporting the entire operation of a production. The consideration of a production as an entity is one of the main aspects of this initiative. Therefore the Guideline describes amongst others the interaction between

*production management systems <-> control and automation
devices <-> machines and equipment*

This leads to another important international standard named:

Enterprise - Control System Integration (IEC 62264, Parts 1 to 5)

This quite complex standard describes the role of control systems on different enterprise levels and their interactions amongst each other. It has to be considered as an engineering guideline rather than a detailed implementation description. Figure 1 shows the layer model of production enterprises in a general manner.

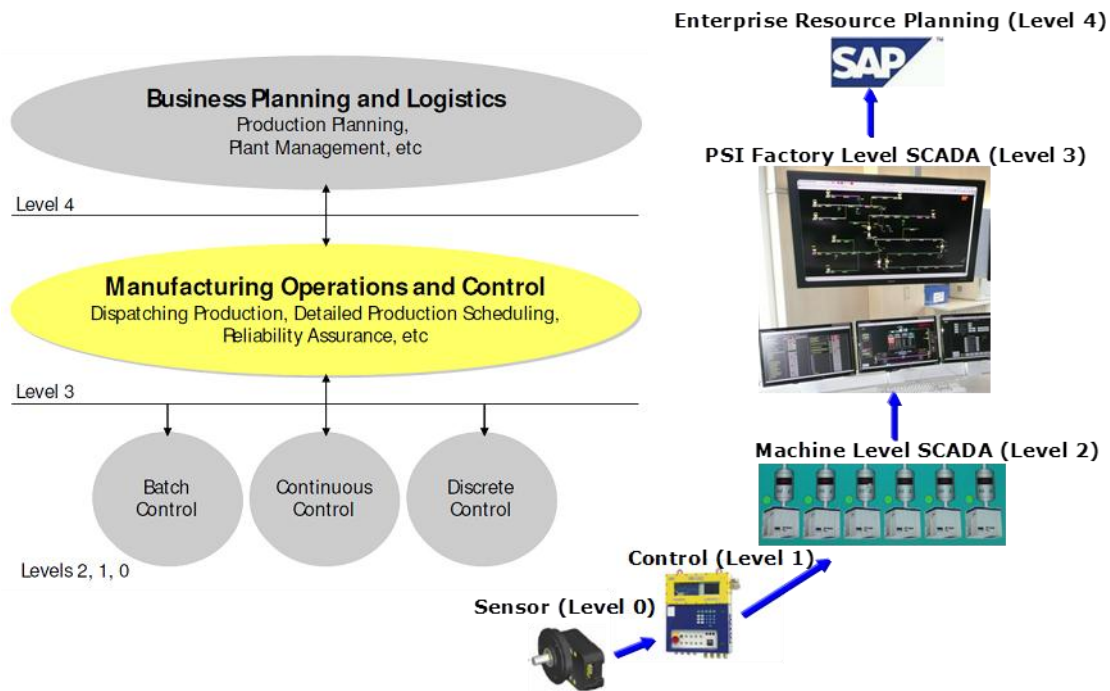


Figure 1: Factory Model according IEC 62264

The tools and systems realizing the “Digital Factory” and hence the “Digital Mine” are located on the manufacturing operations and control level (Level 3). Real time data is provided from and transmitted to systems on the lower levels (i.e. PLCs), data relevant for the business planning and enterprise logistics are provided to systems on level 4 (i.e. ERP- and related systems).

Focus of the manufacturing operations management is production control. But production control has a number of connections to related functions and activities as shown in Figure 2. These functions are not limited to control or automation functions but also comprise manufacturing execution functions (MES) like planning and workforce management. In Figure 2 the MES-related functions are highlighted in grey.

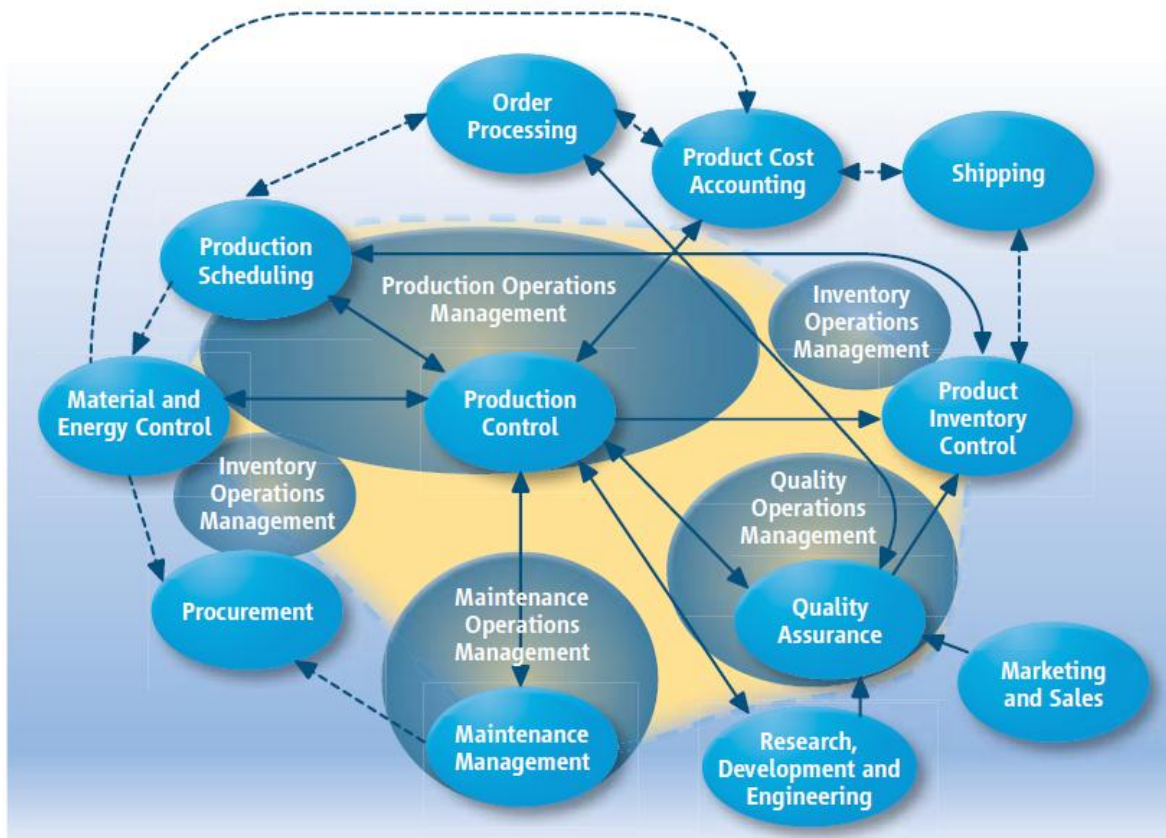


Figure 2: Manufacturing operations management model according to IEC 62264-3, Fig. 1 [4]. MES-relevant areas are highlighted in gray

As shown in Figure 1 *PSImining* is located on level 3 of the factory model and as high level SCADA- and workforce-management-system is therefore in the position to realize the “Digital Mine”. How this is achieved is described in the following chapters.

In respect to the functions given in Figure 2 *PSImining* is covering the following functions distinguished by aspects of control, planning and workforce-management:

Control:

- *Production Control*
- *Energy Control*
- *Quality Control*
- *Product Inventory*

Planning:

- *Production Scheduling*
- *Energy Consumption*

Workforce-management:

- *Production Management*
- *Maintenance Management*

- *Inventory Operations Management*

Information available in and generated by *PSImining* support systems located on level 4 in respect to:

- Production Cost Accounting
- Procurement (i.e. spare parts and consumables)
- Production Scheduling
- Quality Operations Management

According to the definition of the “Digital Factory” (Digital Mine) *PSImining* fulfills the requirements for being a set of tools supporting the entire operation of a production and considering as a functional entity.

The term “Digital Mine” or “Digital Mining” can also be found in the context of data mining, data storage and retrieval mechanisms. This is **NOT** the Digital Mine we talk about in this document!

2. Targets of a Digital Mine

The purpose of a Level 3 SCADA and workforce-management system is to improve the overall productivity of an operation, considering it as an entity, to achieve transparency for production processes, support and accelerate management decisions.

Improvement of productivity needs to take into consideration:

- Equipment availability and efficiency (OEE)
- Dependencies and relations in-between sub-processes and related machinery
- Exact and real-time information about equipment stand-still (planned or unplanned) or any other events influencing the production process which are monitored by the “Digital Mine”.
- Quality of raw material (coal quality)
- General operation conditions like climate (CH₄, CO₂, CO, temperature, humidity, etc.)

A Level 3 SCADA and workforce-management system has to integrate all operational aspects into one system and to relate all sub-systems to each other in order to provide:

- combined and condensed information from all systems involved
- maximum support to unload operators from searching information especially in case of events, alarms or even accidents
- analyses and reporting to operations management for the entity of the involved processes
- system support for manufacturing execution beyond machine level
- records of all actions and events occurring during operation time

By implementing PSImining as a Level 3 SCADA and workforce-management a mine operator (i.e. Shendong) will achieve:

- to realize the integrated mine management
- to realize optimized production management
- to realize real time production support
- to support mine staff to accumulate the experience and improve skills
- and as consequence: to realize the “Digital Mine”

3. Main control functions of the Digital Mine

By implementing PSImining as Level 3 SCADA the system shall supervise, control and manage the equipment, machines, production resources and mine workers in a “digital way”.

The main areas of such supervision and control are:

- Supervision and control of all equipment in the coal-face (shearer, shields, AFC, high-pressure sprinklers, ...)
- Coal face and seam visualization, including diagrams showing the percentage of coal/stone in production, shearer position, shield heights and pressure on shields, etc.
- Infrastructure monitoring including electrical network, water drainage, pressured air, N2-supply, etc.
- Conveyors/Belts/Bunker supervision and control
- Standstill monitoring for machinery and transportation equipment including conveyors, shearer, ploughs, etc.
- Geographical large overview picture to relate the geographical location with the machinery, people, supply material, maintenance material, etc.
- People/transportation tracking
- Safety and ventilation
- Mine security
- Video integration (CCTV), event-driven video control for operator support

Each element of the list above may serve as headline for a detailed description. **Please refer to other documents (i.e. Features, Goals and Benefits of PSImining) for further details.**

PSImining as the tool for the “Digital Mine” is prepared to provide the features mentioned above under the precondition that the necessary data from underground equipment are available to PSImining (Level 3 SCADA).

4. Main Management features of the Digital Mine

The concept of a Digital Mine (analog to Digital Factory) should **never** be considered as a “fully automated system” without any intervention by human beings (operators). A mine operation (like all other production sites) is characterized by unforeseen events day-by-day. Only human beings with their ability of gathering experience, creativity and phantasy are in the position to handle unforeseen events. An automated system can handle known events which are implemented in software.

Therefore PSImining focuses (amongst other features) on supporting the operator!

This is done by sophisticated means of visualization supporting the real time monitoring of the mines. These means of visualization start with the system support of the operator which prevents him from “searching information” but directs him to the point of interest. These mechanisms are supported by an operators work environment which provides him with a combination of large-screen-displays and monitors as one single (logical) working area.

Such working places are either located in a Central-Control-Centre (CCC) where from one location several mines can be supervised or in a Local-Control-Centre (LCC) which focuses on the operation of one mine. A combination of both is of course possible. The CCC can be considered as the “situation room” of the mines under control and hence is decision making center of the mine.

The operators shall manage the production through clear division on individual specialization, for example tunneling, conveyor, infrastructure, staff and transportation. By integrated management, the productivity will be improved, the logistics will be optimized and the efficiency will be maximized.

Production on demand

The trend in coal industry is to have an optimized production management, which means to implement a market driven “pull strategy” which means: Production on demand!

In order to realize the pull strategy / production-on-demand, which means to organize the production based on the market requirements (quantity, quality etc.), then only a Level 3 SCADA system is in the position to manage this, since these are tasks clearly above automation level and in combination with Level 4 (ERP).

Real-time and precise decision making support

The integrated data management defines the logic and the relation between the data thus turning data into meaningful information. This enables the operators to analyze the

reason or the source that is caused the production events. The operators can be partially or fully authorized to realize the on time and precise decision-making and adjustment.

Meanwhile, the mine managers can also solve timely and precisely the issues, which need to be reported to them, through remote access with the same data source as the operators.

Through this, mine managers will not become the production decision-making bottleneck, and the operators in different levels are also authorized to handle the issues within their authorized area.

Improve experience and skills of mine staff

One of the main purposes of a CCC is sharing of know-how. Whatever model of work partition is implemented the operators in a CCC automatically share all information discussed and handled by the CCC. Thus they participate in all events which occur in the one or the other mine and are therefore in the position to apply such know-how to their area of responsibility. By daily participation in this process, it helps to improve the people's management and decision-making capability.

Based on above description, PSImining solution provides unique Level 3 SCADA system, to realize the integrated management for machinery, conveyor equipment, infrastructure and staff. Meanwhile, through the logical database, the strong decision-making base is provided. The PSImining solution also realizes the mine specific functions, for example GEO information management, safety position of conveyor/banker/staff. Through this system, Kou Zi Dong mine will realize the digital mine.

5. Automation and Optimization Potentials

One of the main characteristics when introducing the Digital Mine is the improvement of automation and optimization potentials. The reasons for such improvement potentials are obvious when reflecting the main feature of the "Digital Factory":

To consider the operation/factory as an entity.

Automation restricted to a machine or equipment is limited to the data of the sensors and actors related to that machine. Superior information is not available or maybe in a limited way. Therefore only a Level 3 SCADA is in the position to perform automation and optimization functions from a higher level.

In contrast to other SCADA systems PSImining is in the position to include into automation strategies geographical/geological information as well as aspects of workforce management. This is due to the complete integration of these features into one system.

The following lists provide keywords of automation and optimization potentials. Details depend from preconditions (i.e. availability and quality of data) as well as from the targets of the enterprise (i.e. priority of key performance indicators (KPI)).

- Coal-face automation
 - dynamic memory cut by applying dynamic profiles from surveyor data
 - direction control of shearer (mining machines – straight, up, down)
 - automatic speed control by reflecting local or superior preconditions (belt loads, bunker capacity, etc.)
 - collision detection and prevention (shearer shields)
 - goals: dirt reduction, output improvement, OEE, etc

- product flow optimization
 - continuous product flow, peak load prevention
 - deliver required coal quality and quantity
 - offline simulation for planning purposes (support for operation planning, future mine design)
 - improved equipment planning and layout (oversizing/undersizing)

- coordination and optimization of production resources
 - water for sprinkler
 - material logistics for tunneling
 - transportation scheduling and load optimization
 - electrical energy management

- Dynamic work force management (reduction of personnel in dangerous areas)
 - operation planning and management (people, resources)
 - maintenance of complete mine equipment, machines and infrastructure; dynamic workforce management using stand-still periods, improve OEE by reducing fixed-hour maintenance
 - dynamic production schedule by considering unforeseen events

This list above is by no means complete or comprehensive. Automation and optimization goals are dependent from many factors starting from automation point of view up to strategically targets of the enterprise.

Therefore automation and optimization projects should (not only) be invented on the “green planning table” but should also be inspired by the daily events in a mine operation. *PSImining* offers a comprehensive supervision of all processes, equipment and machinery of a mine. Therefore the following **5 steps to high level automation** should be taken into consideration inspired by daily work:

1. monitor and classify events
2. identify possible systematic behaviour of events
3. determine and apply the rules how to manage/solve the events (operator intervention)
4. implement the rules/strategies into software

5. apply the SW by operator intervention (semi-automatic) and in case of successful solution apply it as an automation feature

This procedure empowers an operator to implement High-Level-Automation features according to their needs and goals and therefore give further added value to the investment of a Level 3 SCADA.

6. Organizational and Management Implications

With the introduction of a Digital Mine the work partition, functions, rolls and responsibilities have to be adopted. If this aspect would be neglected considerable potentials of improvements can't be realized.

In the past 20 years there was a development in modern and highly automated mines, where the supervision of the processes and, as a consequence, the responsibilities for such processes went away from the machines involved to local, underground control areas where operators were located in underground cabinets equipped with few ruggedized monitors and control panels.

The increasing power of digital communication networks (based on i.e. coaxial and fiber-optic cables) offered the possibility to make all underground data available above ground. Advantages of such above ground control rooms are obvious and will here not be considered in detail (security of people, standard equipment, lower labor costs, lower infrastructure costs, etc.).

Above ground control rooms can be designed under various aspects. For the following considerations it is assumed, that in the above ground control room several mines shall be supervised, controlled and managed. Hence the purpose of this room is to serve **Central Control Centre (CCC)**.

In general the following functions related to supervision, control and management of connected mines will be performed in such a CCC (the list does not imply priorities, rolls and responsibilities may be implemented step by step):

- Supervision and control of all equipment and process values in all coal-faces
- Supervision and control of conveyors, belts and bunkers
- Infrastructure monitoring including electrical network, water drainage, pressured air, N2-supply, etc.
- People and vehicle tracking
- Safety and ventilation
- Mine security
- Video integration (CCTV), event-driven video control for operator support
- Standstill monitoring for machinery and transportation equipment including conveyors, shearer, ploughs, etc.

- Geographical large overview picture to relate the geographical location with the machinery, people, supply material, maintenance material, etc.

A simple but straightforward work partition is a dedication of operator places per mine as shown in Figure 3. One (or better 2) operators will be responsible for one mine and dealing with all operational and management aspects of that mine.

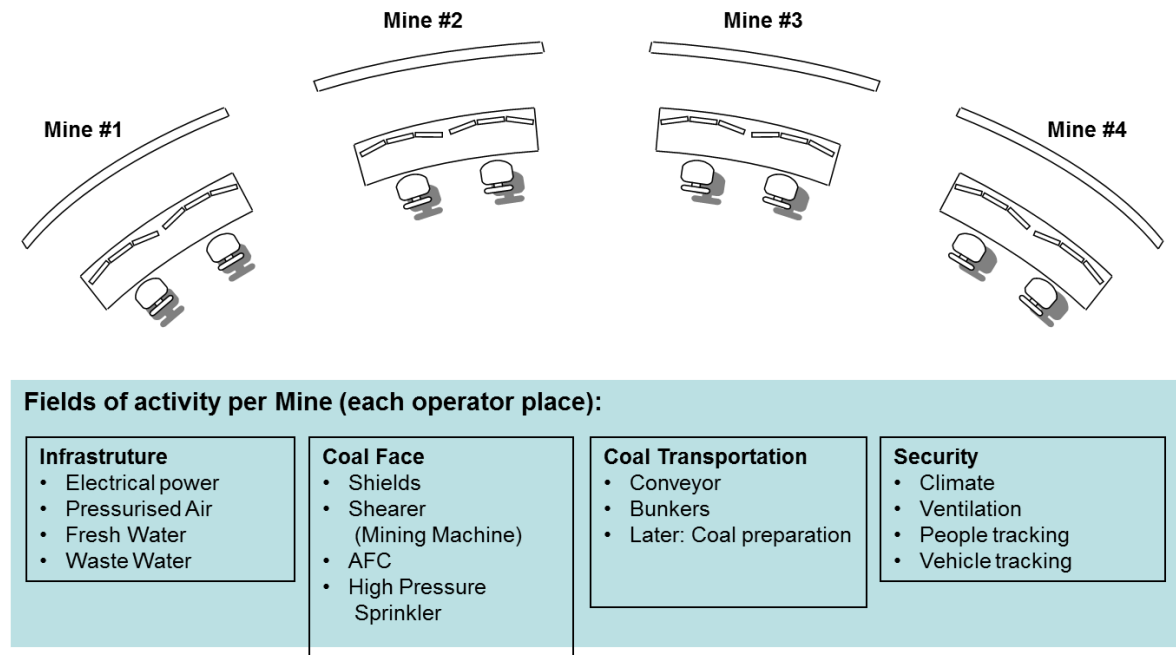


Figure 3: Control room layout for operator responsibilities per mine

Another concept of partitioning the work is given in Figure 4. There the work partition follows functional and know-how aspects. This type of work partition supports the improvement of the know-how related to the equipment and machines under supervision as well as the know-how about the management aspects for the area of responsibility.

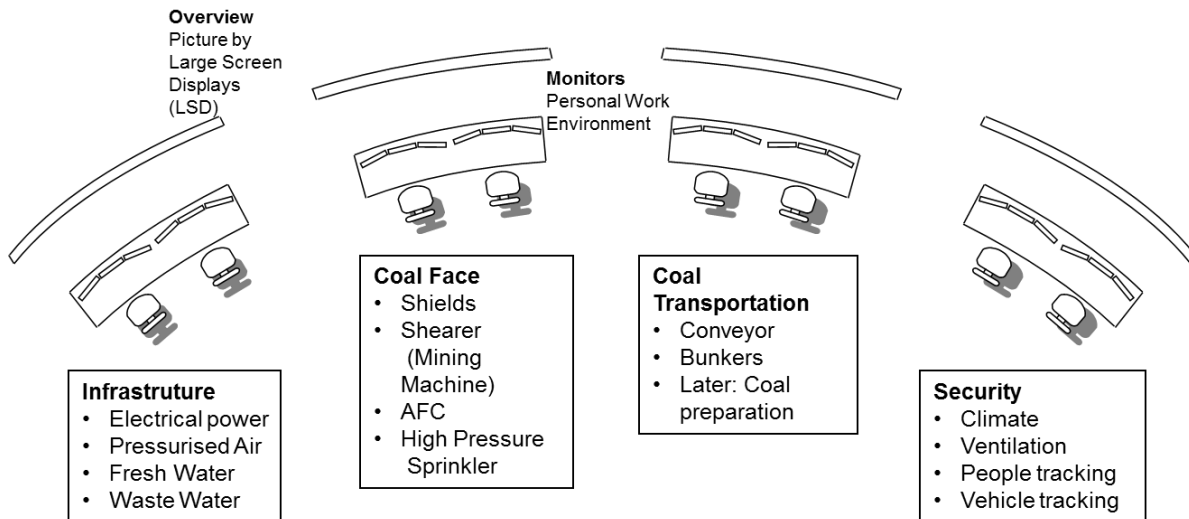


Figure 4. Control room layout for work partition per function

Both layout and responsibility alternatives as well as any mixture of them have their own advantages which need to be reflected case by case. Such reflections should also include reporting lines and distribution of responsibilities.

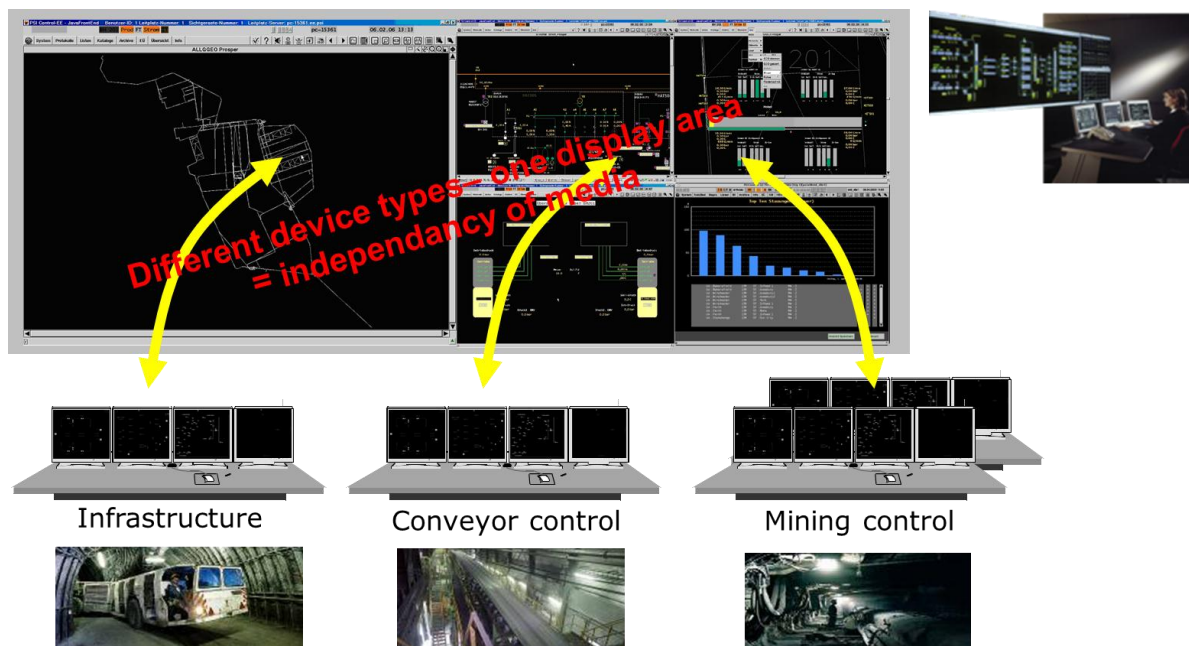


Figure 5: Operator place with monitors (detailed views) and large screen displays (overview, global views).

In respect to work partition the following principles should apply:

- Decision should be made where the best information is available. With realizing the Digital Mine this is naturally the CCC or LCC.

- Management actions should be made immediately for efficiency and safety reasons.
- Decision bottlenecks should be avoided.
- Clear rules how to solve conflict situations (i.e. contradicting instructions, priority of underground/above ground decisions).
- and others more

7. Future Goals

Besides the automation and optimization aspects provided in chapter xx there are of course other potentials to be explored. Which priority they have depends on the enterprise targets.

Nevertheless some ideas are given below as keywords:

- improvement of security predictions of hazards (speed, direction and concentration of gas clouds)
- integration of coal preparation plant inclusive impact/reaction on the mining process
- integration of coal loading and related logistics
- improved energy management (relating to production peaks, consumption predictions by daily consumption distribution)
- improve relation of data between systems and equipment involved in coal production
- integration and coordination of external resources (energy, transportation capacity, spare part availability, ...)
- and others more

8 . C o n c l u s i o n

The Digital Factory and hence the Digital Mine is not a buzz-word or a marketing slogan it is a concept pursuing the goal to consider a production as an entity (i.e. coal mining).

This implies that models, methods and tools shall give a comprehensive overview and access to the entire installations of a mine (equipment, machines, infrastructure, tracking, etc.).

PSImining supports the goals of a Digital mine in respect to supervision, control, automation, optimization and workforce-management. It combines high level SCADA functions together with MES functions for planning and management tasks.

PSImining is based on proven SW-technology installed in about 100 large to very large SCADA projects.