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Computer Aided Lignite Mining in the Rhineland Lignite Mining Area

E. DERMIETZEL, G. BINGEL and P. REUSCH

Rheinische Braukohlenwerke AG, Köln, Federal Republic of Germany

The fundamental ideas of Computer Aided Lignite Mining (CALM) with respect to hardware and software used at Rheinbraun are explained and outlined in detail. The computers used in the main data processing department and in the different departments in the mines are described. Special emphasis is laid upon the network connecting the computers at different places for data-exchange.

Concerning technical applications, the main facilities of CALM are deposit and pit modelling, complex geomechanic computations and mass calculations, data recording from the production process in the pits and refining plants, and detailed information and planning systems for water management and mining equipment.

Concerning administrative applications, the main facilities of the software are the accounting system with cost controlling and planning, the materials management system with stock control, forward planning and computer supported order procesing, a system for the administration of property within and surrounding the mines, and systems for personnel administration and payroll.

The various software systems developed for these application and the influence of data processing technique, such as data base management and the interconnection of data processing systems, are demonstrated.

Introduction

The Rheinische Braunkohlenwerke AG (RHEINBRAUN) today operates one of the largest opencast mining areas in the world. With the help of modern technology 120 million metric tons of lignite are mined annually.

85 % of the coal is used in power stations owned by the Rheinisch-Westfälische Elektrizitätswerke AG (RWE). With a capacity of 12 000 MW, the Rhineland lignite field is the most important electricity generating centre in Europe. 15 % of the coal is used to produce briquettes, pulverized lignite fuel and coke.

Today, the opencast mines have a depth of up to 350 m. In future, however, they will reach depths of more than 500 m. Because of these depths 450 million m^3 of overburden have to be removed, transported and dumped every year.

A prerequisite for mining at such depths under existing hydrological conditions is the withdrawal of groundwater. The basis of economical mining under these circumstances is a highly developed information technology.

The elements of the open-pit systems are the staff, the solid rock, the winning excavators, dumping

stackers and conveying plants, the maintanance equipment and a number of important ancillary units.

The various interacting technical and administrative departments are a cybernetical system in a complex environment.

The environment of the system is determined by changing governmental and legal conditions concerning such various aspects as the definition of the boundaries of the mines and excavation planning or the taxes payable by the company.

The operating cycle of the pits is the consequence of numerous decisions between the above-mentioned subsystems. To make decisions on every level of management it is crucial that all executives responsible for planning, controlling, and distribution have all the actual information about the operating cycle and working conditions they need.

The increasing influence of data processing systems (DPS) on solutions of technical and administrative problems in the Rhineland opencast mining area has led to the development of a DP oriented conception of COMPUTER AIDED LIGNITE MINING (CALM) at RHEINBRAUN during the last ten years.

Data processing equipment

Rheinbraun has successfully developed an aligned methodology for the company's use of computers. It encompasses the most significant aspects about modern data processing.

(a) The various technical problems of opencast mines must be handled in an effective and economical way.

(b) Different computing techniques require adaptable forms of organization and operation.

(c) Suitable techniques of planning and controlling are prior conditions for an effective data processing operation.

(d) Owing to the geographical location of the mines data processing capacity is not only used centrally but also distributed at the production face.

(e) A time-sharing network links the users to central processing units. Additionally, decentralized computers provide local facilities in various sites of the production area.

Concept of distributed processing

The underlying concept is the interdependence of centralized and decentralized processing.

The data processing capacity provided at headquarters is used for applications with a high degree of integration, above all administrative applications, with large data bases supplying centralized data storage for a variety of users. The computer centre takes care of storage and processing of mass data. The high-speed computers available there are needed to perform number-crunching operations primarily for the solution of technical and mathematical problems. The output of the centralized DP system can be delivered to any desired place via teleprocessing networks and terminals.

The main items in the application of the decentralized computers are:

(a) Settlement of a multitude of medium-sized calculation operations in a regionally limited area (e. g. for mine planning and survey).

(b) Data collection and prompt evaluation of local data quantities for operational

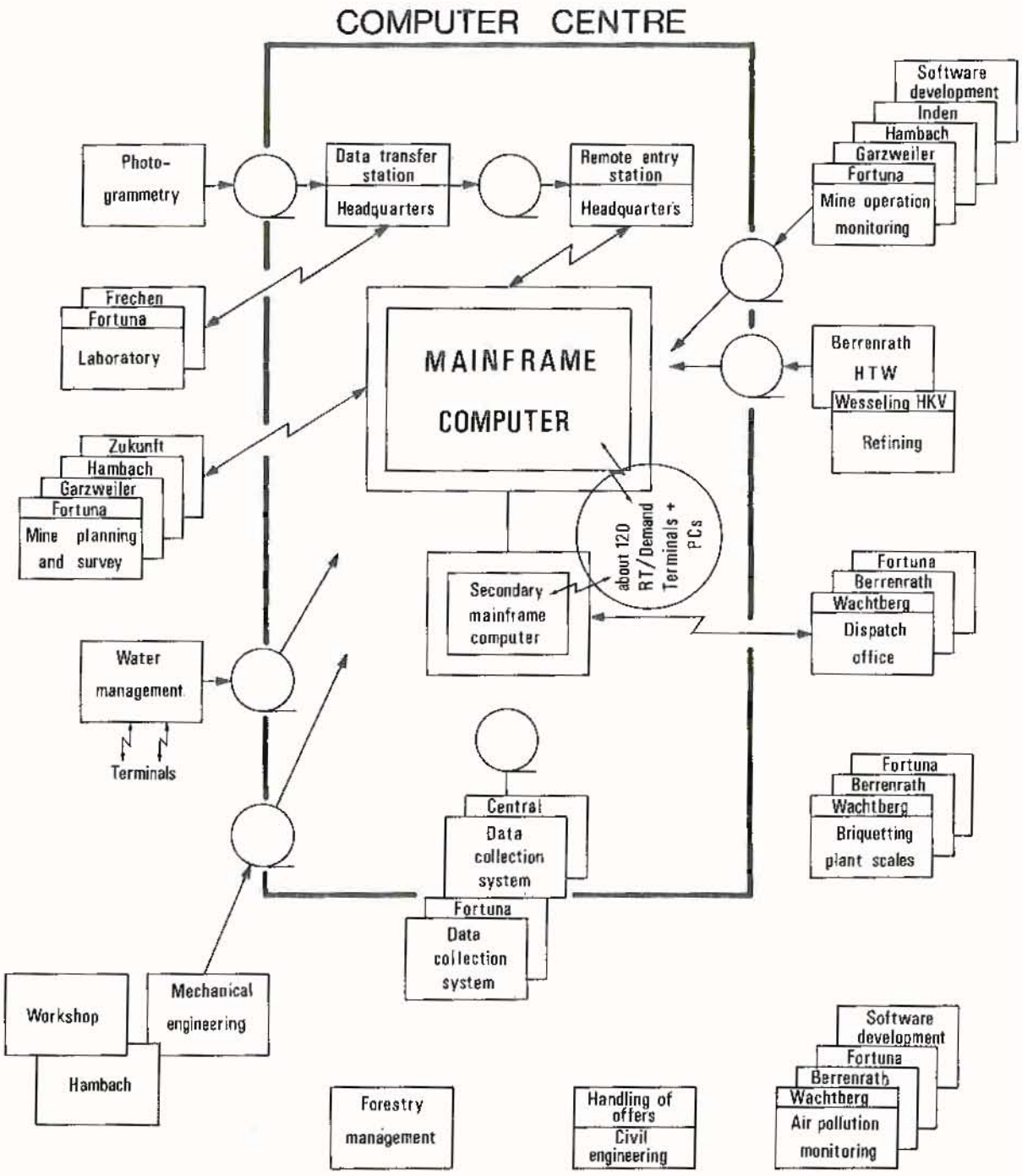

FIGURE 1. Computer networks

arrangements (e. g. for water management).

(c) Operational control and data logging by means of process computers.

(d) Special fields of application without a priority for integration (e. g. management of forests).

For further evaluation and long-term filing the results of decentralized data processing can be transferred to the computer centre via data medium transport or telecommunication networks.

The total data communication network is outlined in Figure 1.

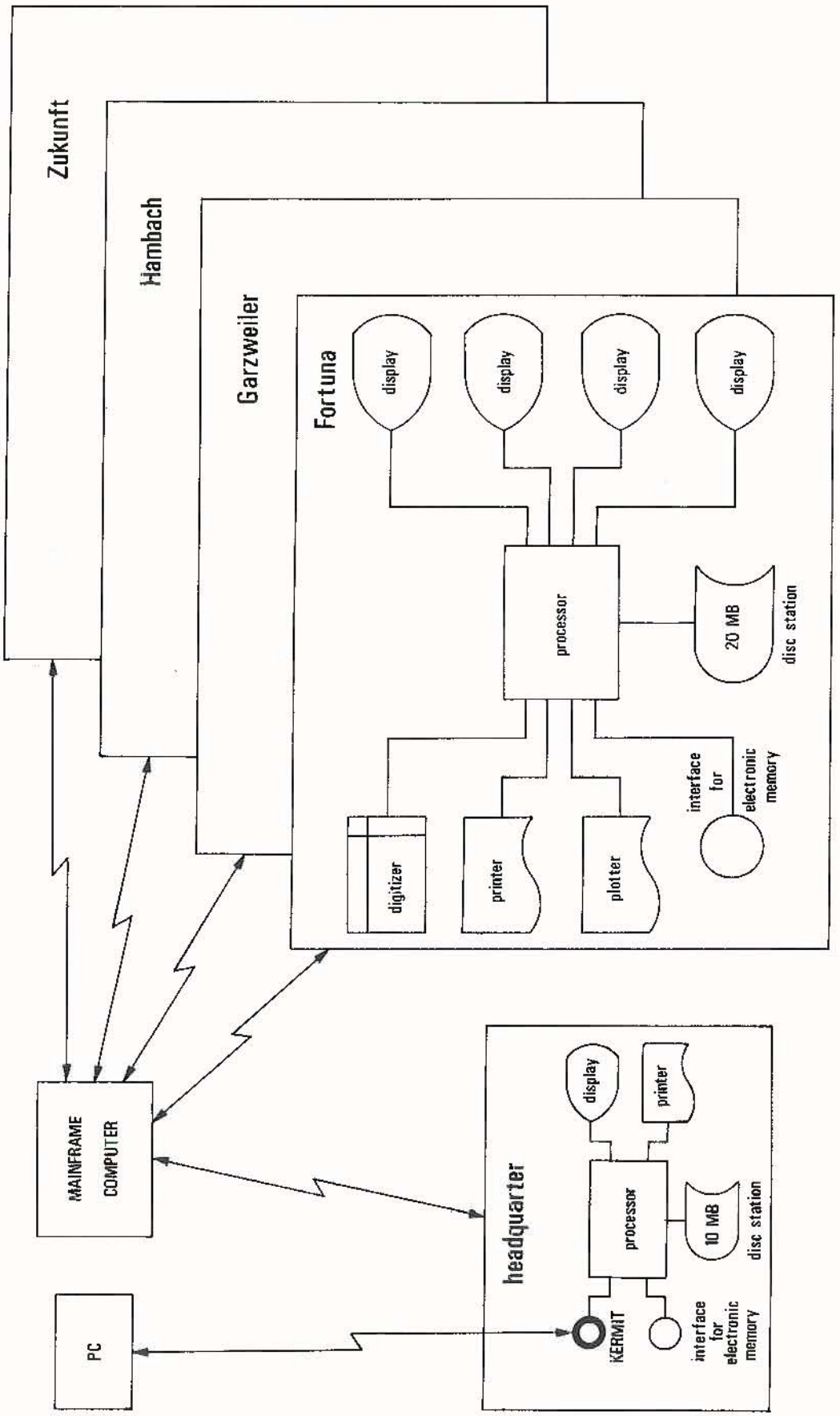

FIGURE 2. Computer network for mine planning and survey

Mining workstations

The engineering departments at headquarters are conveniently connected on-line to the computer centre via time-sharing terminals. Comprehensive software systems are operated as computer aids for mine planning, geology, geomechanics, surveying, photogrammetry, water management, mining damage, structural and mechanical engineering, operations research, and profitability calculations.

Mining engineers, surveyors and geologists in the field use dedicated computer workstations developed especially to meet the data handling needs of mine planning and survey at remote sites. With this mining workstation at their site the mining staff have immediate access to the computer power and graphic capability they need to digitize data from maps, to load data from self-registrating tacheometers, to calculate, enter, edit, and store coordinated data. In-situ acquisition of data reduces the time taken to build an error-free file of geologic or mine-design information. In-situ administration of local coordinate files (check points, control points, conveyor systems) is aided by data manipulation capabilities of the mining workstation as well as by elaborate software for data interpretation. Whenever necessary, the mining workstation can serve as a remote terminal of the central computer, connecting the user with the central data bases and mine planning systems. The configuration of a typical mining workstation is shown in Figure 2.

Computer for water management

All drainage activities and hydrological information is recorded on a computer system with a network of its own connecting terminals in remote places, shown in Figure 3. The drainage scheme is checked and controlled by the data acquisition aids provided. The quantities of elevated and discharged water are entered either at a special data collection office or directly on site by the well inspector. The results of water analysis are contributed by the laboratory staff and data about pumps and motors by the pump control office. All system users are guided by a strictly dialogue-oriented software environment. This guarantees a maximum of data integrity. Since only recent data are relevant for current inquiries concerning the actual draining, the data are transferred periodically to the central computer via magnetic tape for further evaluation and reports.

Mine operation monitoring computer

An essential part of the CALM information system is the use of process computers logging every change or discontinuity of mine operation. This is achieved by scanning all conveyor control and belt-scale signals 24 hours per day. In a conversational mode the attendants have to complete the automatically registered data records with codes for the kind of produced material or cause of delays respectively. The transport of coal to the different power stations, briquetting and refining plants, and the transport of waste to dumps in other sites by the company-owned railway system is also recorded fully automatically on the mine operation monitoring computer, which telecommunicates with the train control equipment.

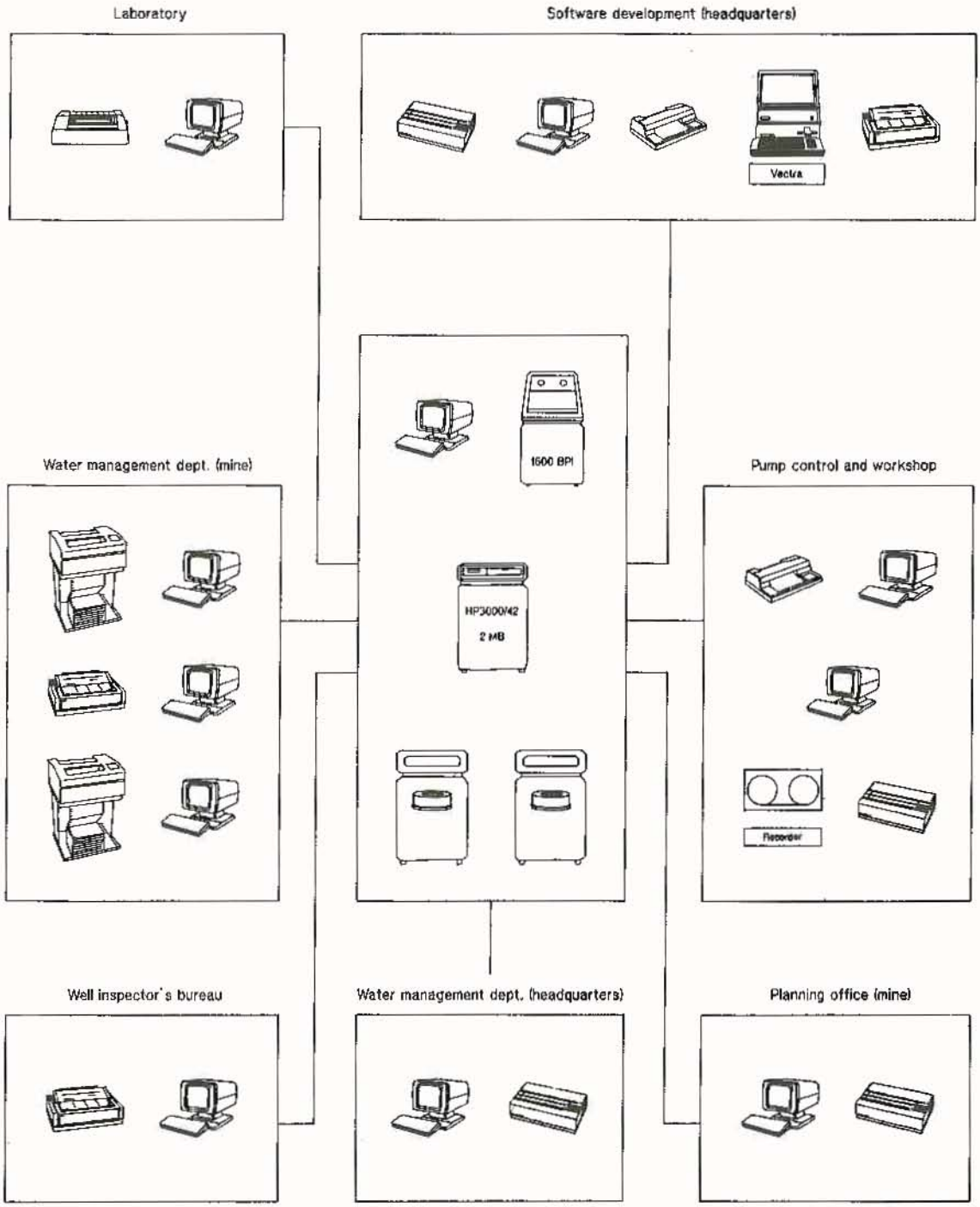

FIGURE 3. Water management computer

The signal acquisition and the manual input enable the system to display permanently the state of mine production. Thus all actual information can be prepared in a compact form on displays or printers to support the mine management on every level in their decision-making. The configuration of a mine operation monitoring computer is shown in Figure 4.

Technical applications

A large variety of computer programs has been developed by Rheinbraun covering different aspects of mine planning, operation,

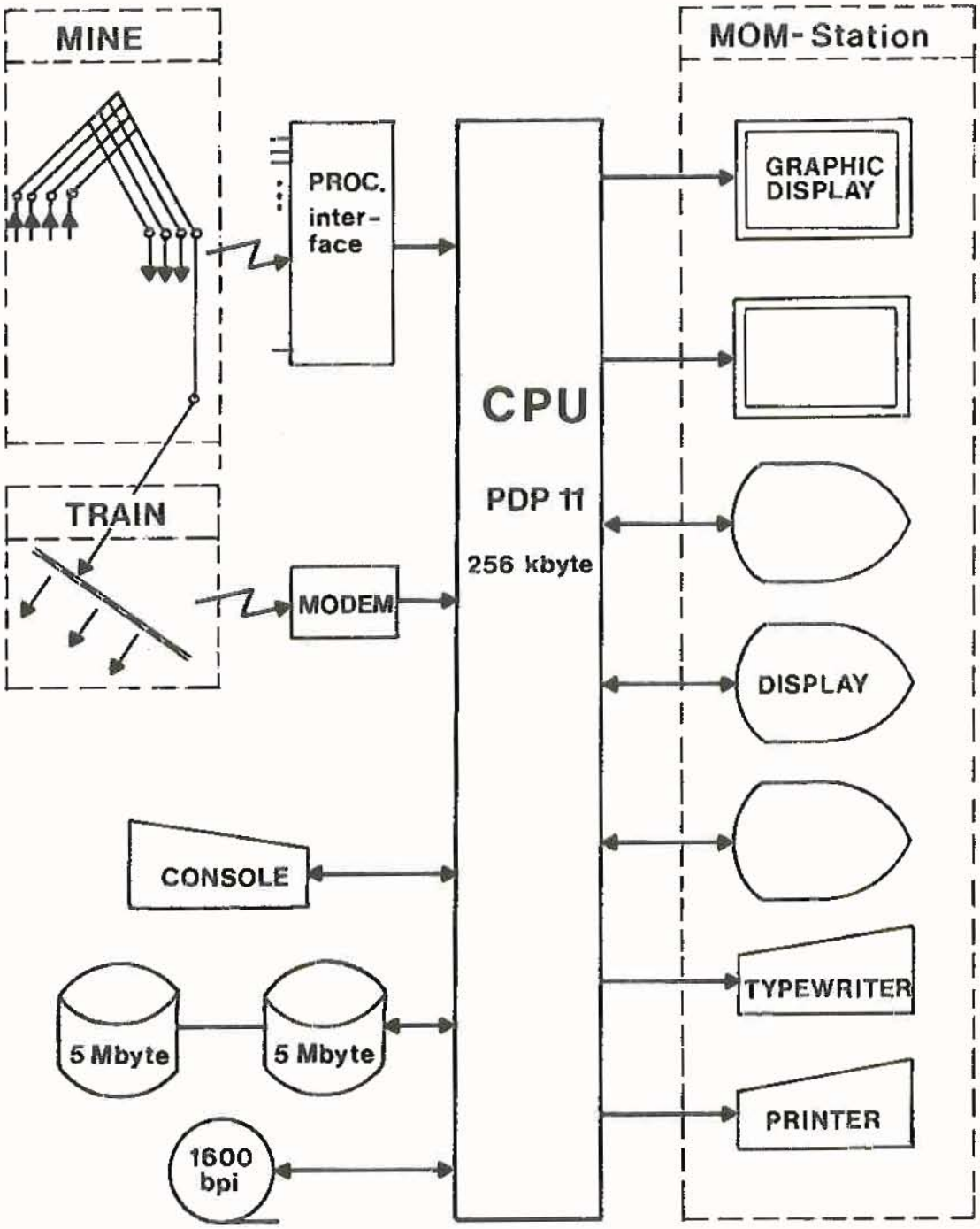

FIGURE 4. MOM-computer configuration

and management. The most important components of CALM in technical applications have been practised already for many years and have been improved continuously.

Mine planning and survey

The heart of the main technical program system is Planning and Geodetic Mass Calculation (PLAGMA). Planning and survey of opencast mines with the aid of PLAGMA are characterized by the following outstanding features:

(a) A multiplicity of users, including departments in headquarters and correlated divisions on five mines;

(b) simultaneous access by means of time-sharing terminals or telecommunication between the central computer and the computers for mine planning and survey in each mine;

(c) access to the central data base with the complete lignite deposit model of the area;

(d) use of a software package in tool-box style, requiring no special EDP-knowledge.

PLAGMA is the fundamental tool that makes data managment, deposit modelling, mine design, and reserve reporting a pushbutton operation. This extensive system of computer programs is designed specifically for modelling and mining a multi-seam coal deposit.

At the time when data are first loaded into computer memory, extensive editing is automatically performed to ensure the integrity of further processing. Corrections and additions are easily made as more data become available. Data acquisition for PLAGMA is done by digitizing, photogrammetry and terrestrial survey.

The seams, overburden and intercalations are represented on geological maps. The working levels are also marked on maps. Digitizing includes boundary lines, contour lines, fault lines, and strings of other points with attached spot heights. Each seam may be subdivided into strata with different inherent attributes, e. g. coal quality. Those data need not be taken from maps, since PLAGMA provides facilities for the construction of the layers and the corresponding quality values from an existing deposit model and selected borehole results. The mine design is in the form of operational blocks. In this case digitizing comprehends the upper and lower boundaries and certain slope gradients on difficult bodies.

Geodetic measurements to determine the three dimensional coordinates of the position of conveying lines, pipes, boreholes, the mine situation, and possible movements in the slopes at control points are taken by ordinary tacheometers, total stations, or by aerophotogrammetry. The terrestrial mine control survey is executed on the computers for mine planning and survey in the mines, where software for all common computations in this field is available. Thus data exchange with the central computer consists of prechecked and presumably correct data points. The analogue or analytical restitution of photogrammetric measurements yields input data for block-adjustment programs for both bundles and independent models. These programs are run on the central computer and prepare well-formatted PLAGMA input data.

With the addition of topographic data a detailed model of the deposit and the mine is constructed. The digital surface models for coal seam top and bottom elevations are computed throughout the deposit and adjusted for outcrop lines and internal washouts. Thickness of internal waste and quality values are carried into the deposit model. Thickness of overburden, interburden and coal are first results during modelling.

The data base organization for surface models in PLAGMA is founded on a local grid for the Rhenish Lignite District. The user-determined grid size depends on the required accuracy and the stage of exploration. The available grid

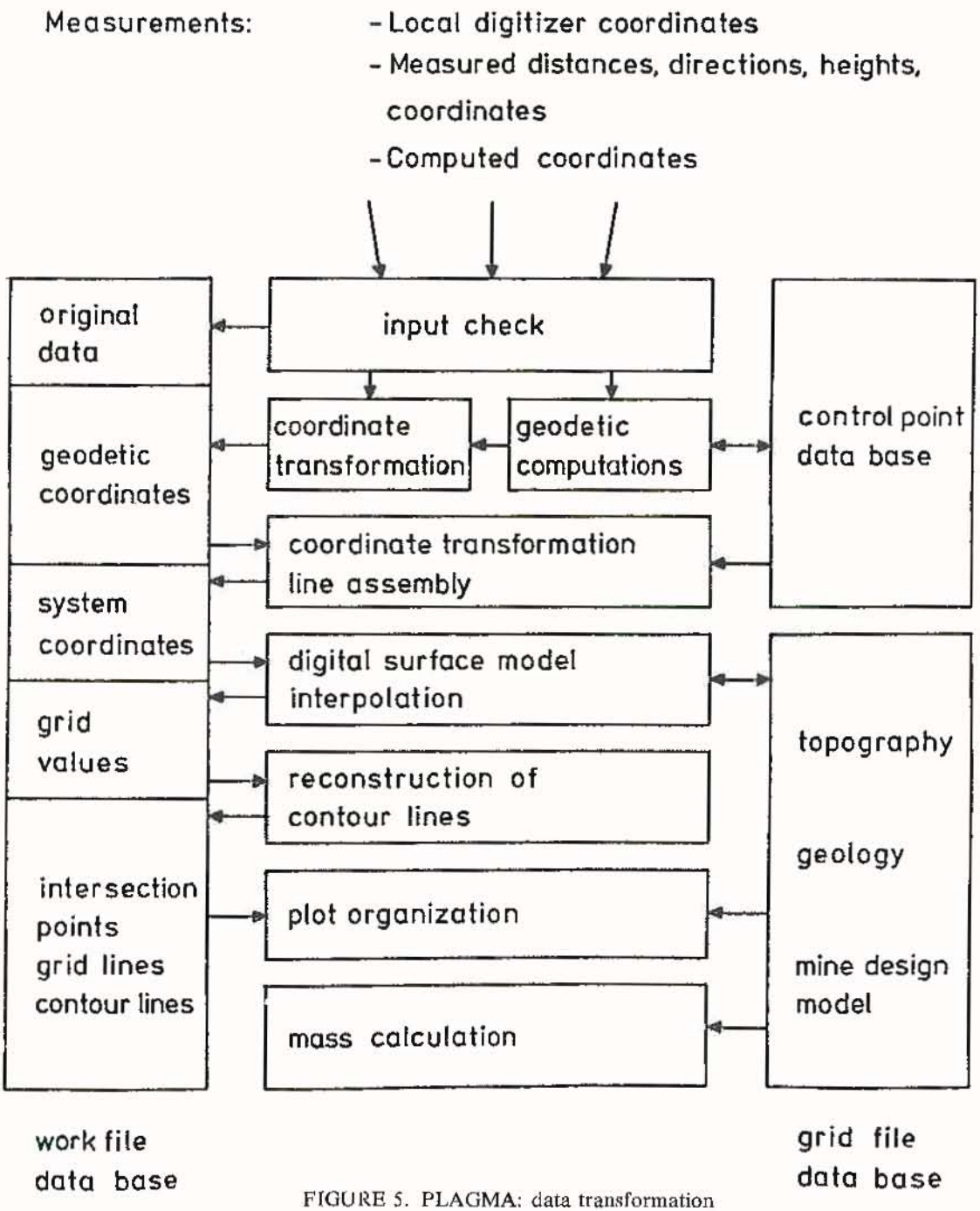

FIGURE 5. PLAGMA: data transformation

sizes range from 2^0 = 1 m to 2^{10} = 1024 m. For each surface in a grid one representative value (height or quality) is stored. With a special kind of packing information in data records and random storage organization a very rapid access to huge data volumes can be achieved. For example, a typical model of a Rheinbraun opencast mine consists of more than 70 surfaces each covering 70000 grids. This model fits in a 10 MB file.

From all digital surface models contour maps and cross-sections can be produced. Figure 5 shows the stages of data transformation in PLAGMA. The main goal is the

calculation of masses for a variety of purposes. Reserves under any area defined by polygon boundaries are presented by seam and weighted totals. PLAGMA can be used for mine planning of individual cuts or it can generate series of cuts across serveral areas.

Geomechanics

For some years the geomechanic department has loaded into computer memory the geomechanic parameters of the soils of the Rhenish Lignite District. With the aid of this geomechanic data base representative geomechanical properties for the investigation of slope stability are determined.

Maximizing slope angles can increase return on investment and reduce costs. Each degree of slope increased could reduce material handling costs by million of dollars or more over the life of the mine. Equally important considerations are slope safety and the catastrophic possibilities of slope failure. Production delays, equipment destruction, injury or death of staff, and costly clean-up operations frequently are the results of slope failure.

With a dedicated application software system the department of geomechanics calculates earth slope factor-of-safety so that angles can be safely increased. The program uses the limit equilibrium methods of analysis to determine the optimum design parameters for a slope. In assessing the stability of an earth slope it utilizes coordinates of a slope surface along with boundaries of all stratigraphic units, various shear strength parameters, and a wide variety of potential pore pressure conditions. After assembling this information a complete analysis to determine the minimum factor-of-safety is performed. This overall analysis often includes more than a thousand factor-of-safety computations. Externally applied line load, berms and surcharges, partial slope submergence, or tension cracks can be handled. The programs produce listings and output files that are compatible with a variety of plotting programs.

Hydrology

Groundwater bearing strata are located above the mining benches of the Rheinbraun opencast mines in depth of down to 500 m below sea level. Suitable drainage policy must be planned on a large scale, and on a longterm basis. Sophisticated digital model calculations are run on the central computer to simulate groundwater flow and to predict groundwater lowering.

The tasks of the computer for water management mentioned before are derived from the drainage operation. In the drainage scheme, the qualities and quantities of the elevated and discharged groundwater have to be recorded for documentation. The well-reporting software system also covers all equipment operating time, power consumption and failures for inserted pumps and motors. Moreover, for pump and motor disposal all technical characteristics and repairs of in-situ and reserve equipment are stored. This enables the drainage department to select the appropriate pump for each well, thus optimizing costs. Miscellaneous reports concerning groundwater withdrawal, groundwater levels, and water delivery to public water supply and receiving streams are produced for the

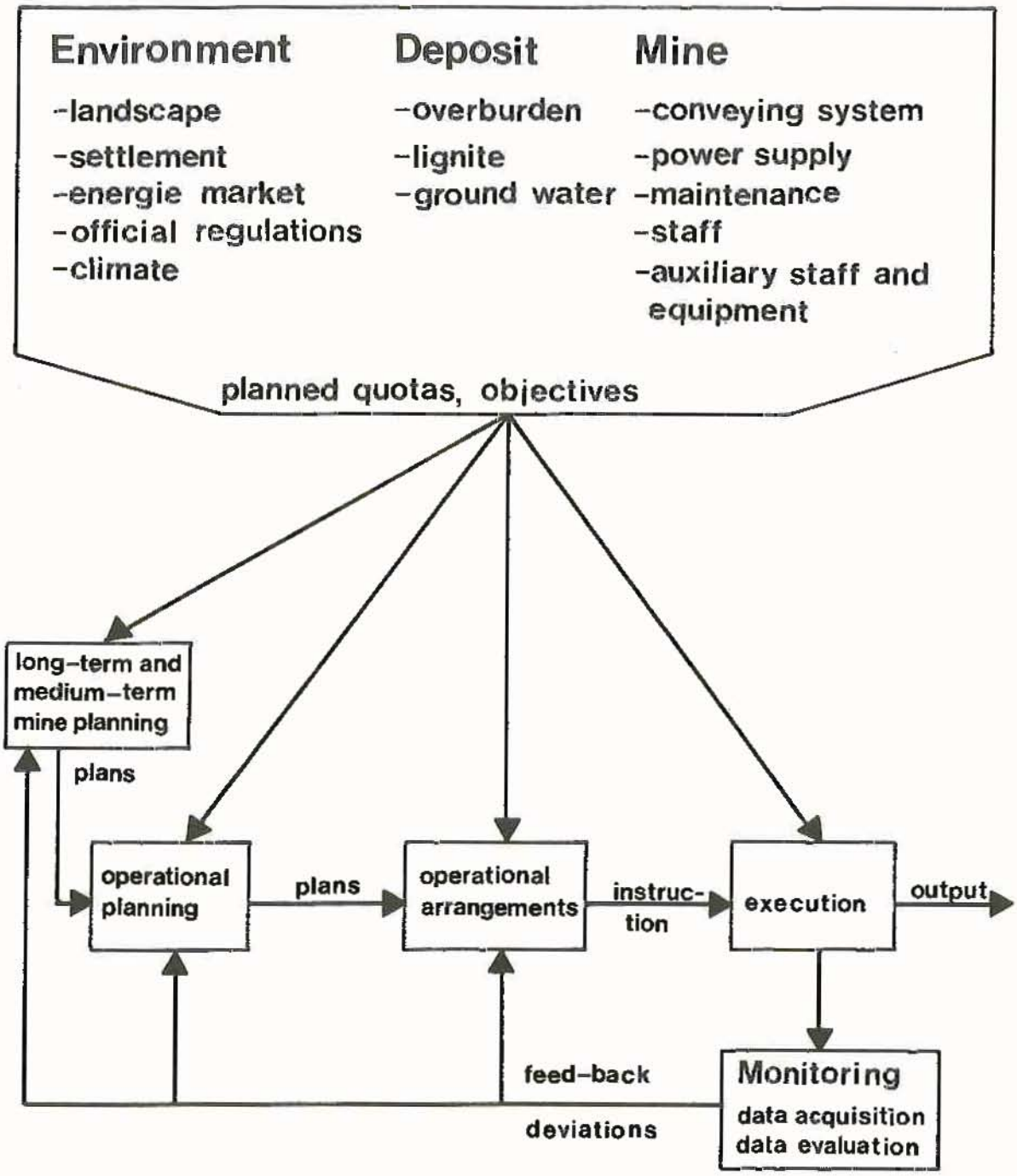

FIGURE 6. Operational control of lignite mines

company's purposes and for the water and mining authorities. A data base system is run on the central computer to administer the large quantities of collected data on wells, piezometers, analyses, and atmospheric conditions, which in some cases reach back fifty years or more. Longterm evaluations in the form of hydrographs, tables and comparisons of planned and actual data are available on plotter and printer. Computer output on microfilm is retained for more than ten years for internal use as well as for evidence of adherence to official requirements.

Mine operation

Figure 6 shows the operational control of the lignite mines in the form of a closed loop. The mine

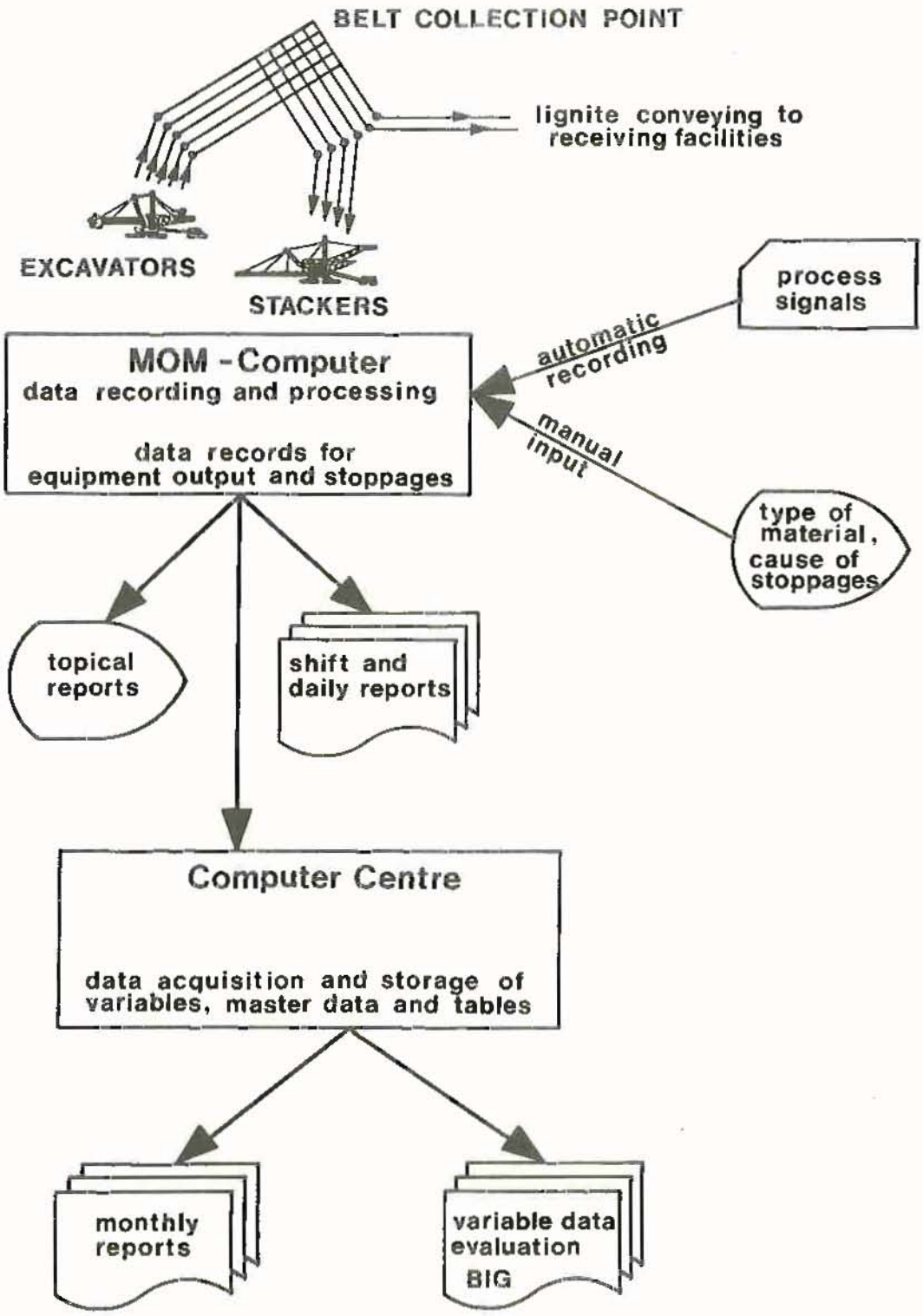

FIGURE 7. Operational data acquisition and processing

operation is variable in time and space and can be characterized by the combination of several key factors, e. g. type of rock, transport systems, power supply, staff, equipment maintenance. Feedback information is needed about the actual state of the mine, and topical information on a variety of subjects makes prompt reaction to malfunctions possible. Coordinating the information in the Rheinbraun mines is the task of the mine operation monitoring system.

Mine management gives a planned quota to the mine operation monitoring station and mine staff who then draw up a planned/actual comparison and make corresponding arrangements. The mine monitoring station informs the mine management of the actual state of affairs.

The overall scheme for acquisition, processing and reporting of operational data is outlined in Figure 7. Input data for the operation monitoring computer are firstly master data with static representation of the conveying systems and rail transport facilities (e. g. excavators, stackers, conveyor links, locomotives, train routes, train loading stations, places of delivery, bunker transfer, belt scales, train capacities). Secondly, process signals on the dynamic state of the mine are received. The signals consist of micro-processor messages on the operation of all elements in the conveying system, indicating smooth running or a malfunction. Supplementary signals record shunting head positions and material flow, belt scale impulses for the transported quantities, train departures, arrivals and transit. Thirdly, some data require manual input (e. g. type of material, cause of stoppages) . The monitoring system generates output on various displays and printers. One display each is reserved for the representation of idle and busy conveyor lines and the train transport. The conveyor scheme and a semi-graphical shift report can be shown by colour display. Automatic printer output is started at shift and daily changeover. Intermediate reports can be called up at any time.

For selective and periodic reports on performance and delays of the opencast mines, Rheinbraun uses an information generator program system on the central computer. All parameters of the output, delays and master data delivered by the mine operation monitoring computers can be coupled and evaluated. The software consists of a self-developed problem-oriented query language operating on a data base and is again a user-friendly application.

Administrative applications

The spectrum of administrative applications

Major fields in administrative applications in the company include

- Accounting/Costing
- Finance
- Planning
- Personnel Management
- Materials management in connection with maintenance and repair
- Property managemant
- Sales management for the distribution of lignite and lignite products.

For each of these fields there are computer based information systems, subsystems of the cybernetical system representing the wohle company.

The administrative applications are based on the central technical applications, such as mine planning, mining, processing/conversion, maintenance/repair, and are interactive with the surrounding environment, for example with communities, owners of property, tenants, suppliers and traders of lignite products.

Figure 8 shows the realm of admi-

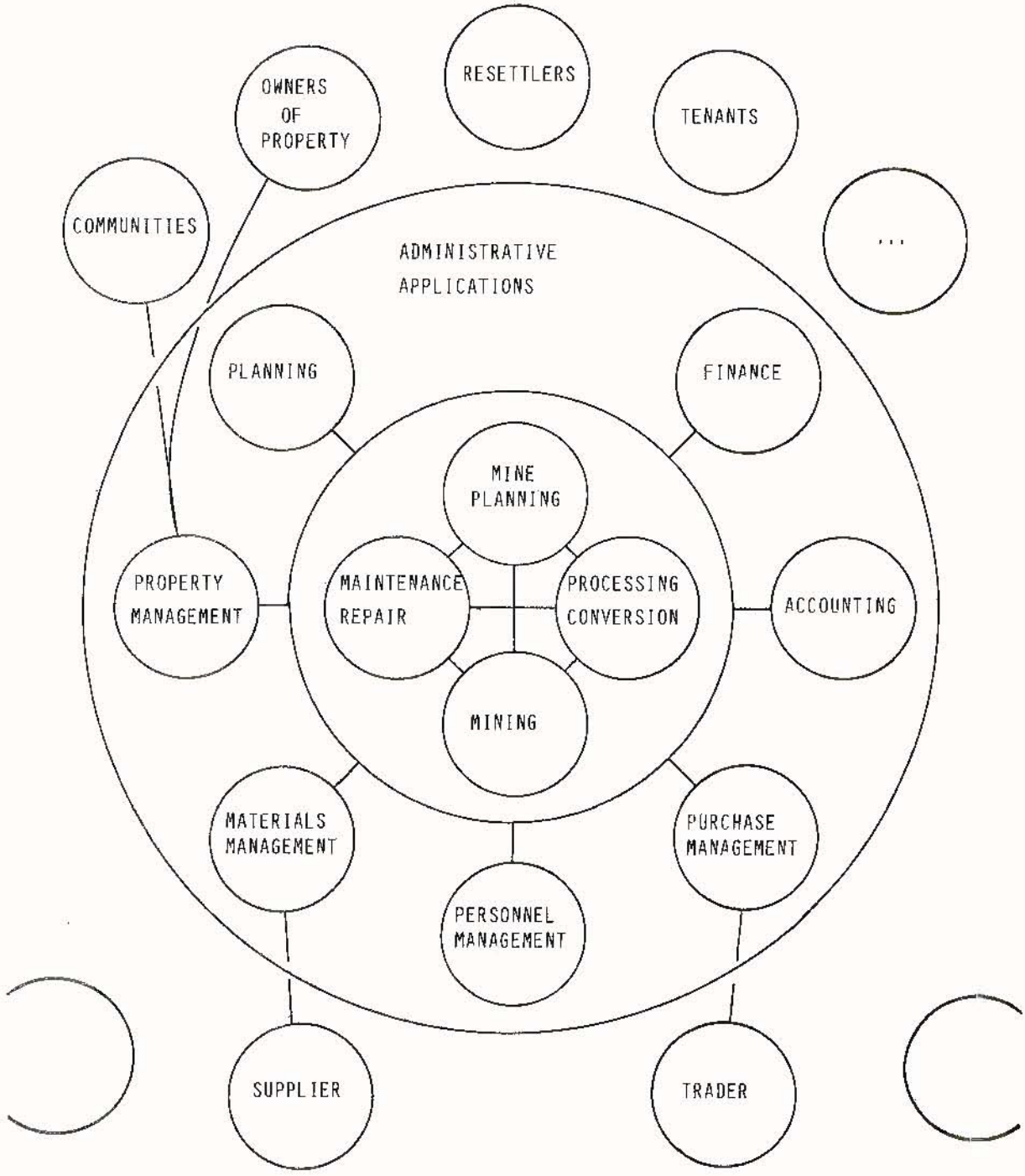

FIGURE 8. Administrative components of CALM

nistrative applications surrounding the major technical applications and shows some partners outside the company. The picture represents the fundamental connections between the various cybernetical subsystems.

In the following sections some of these subsystems are explained, with their typical tasks, components and interacting operations.

Administration of property

The administration of property in an opencast mining company is a sophisticated task dealing with a large number (tens of thousands) of complex objects (properties, rights, contracts, buildings, and so on) over a long period (serveral decades). There are properties owned by the company and properties

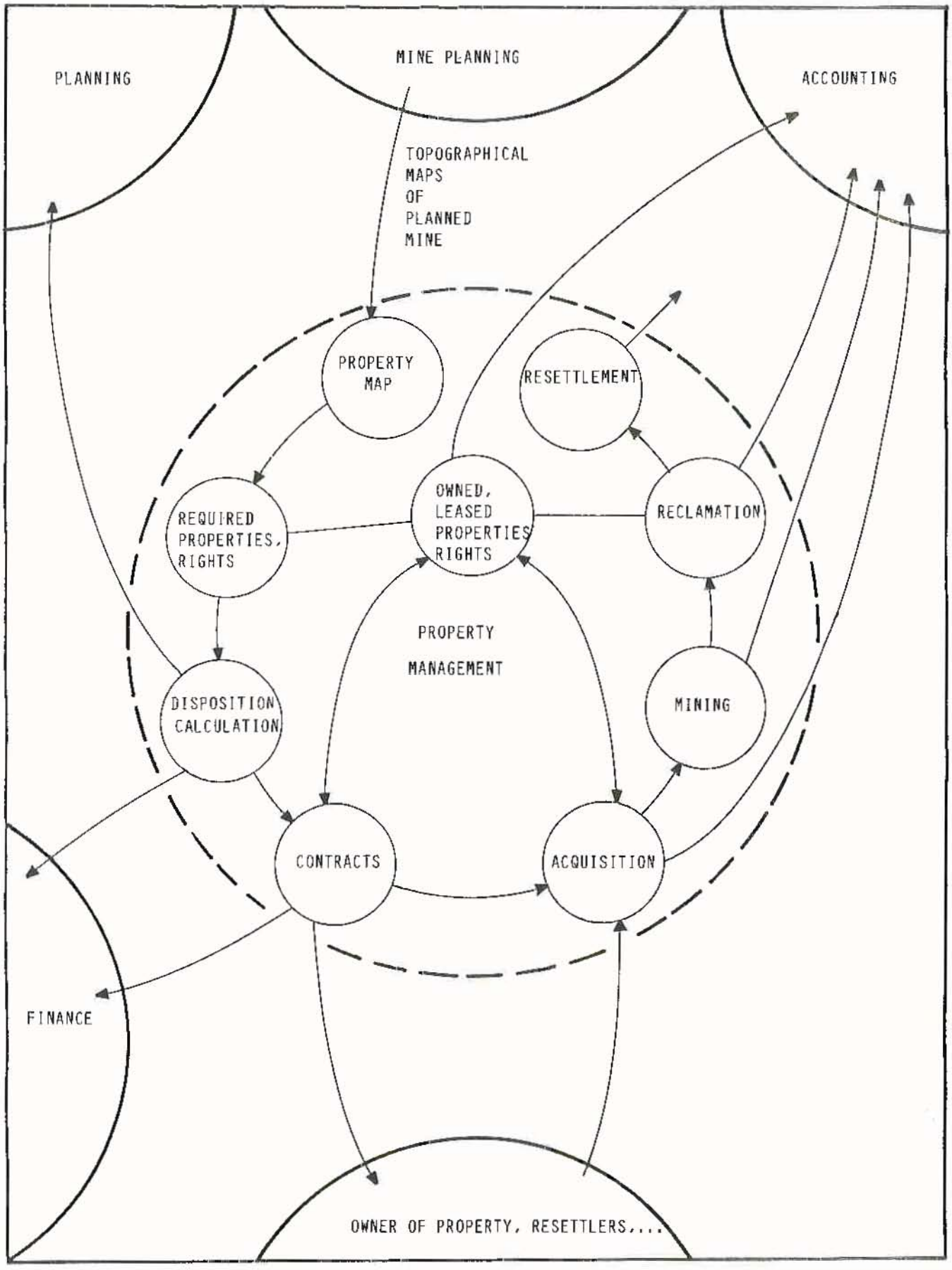

FIGURE 9. Real estate management subsystem

owned for example by resettlers and communities, and properties which are temporary used for mining operations.

Within the borders of a mine, properties are subject to fundamental modifications. Mining activities turn farmland into a part of the open-pit. Overburden is dumped upon that piece of land and finally it may be subject to forestry or agricultural reclamation.

The tasks involved in the administration of property depend both on the activities of the company, such as mine planning, and also on activities of the neighbouring communities and the individuals living in the areas of established and planned mines. On the one hand are long-range planning activities, and on the other short-range trouble-shooting activities, for example dealing with subsidence damage.

The property management subsystem within CALM is represented in Figure 9.

Mine planning submits topographical maps of the surface needed for mining operations. These maps include the borderlines of the planned mine, conveyer lines, sites for wells, planned drainage systems, roads, communication lines, etc.

This input from mine planning represented on topographical maps must be transformed to property maps to create a list of all individual properties, buildings, etc. which are within the borders of the planned mine or are attached to the mining operations.

For the individual property it remains to be determined whether it is owned by the company, or has to be purchased or leased, and the amount of compensation for resettlements and relocations has to be calculated.

After the investigation of the properties, which have to be purchased or leased and after the investigation of the resulting resettlements and relocations, the financial settlement must be calculated and financial disposition established. Finally, contracts must be prepared and transacted. Properties are purchased and prepared for mining operations, so that the open-pit can be developed. Then after exhaustion and final dumping activities, the former pit is subject to afforestation and agricultural reclamation.

The inventory of property, the acquisition, use and reclamation of land are also of course handled within the accounting subsystem, and finance and planning subsystem.

Materials management

The materials management subsystem within CALM is represented in Figure 10.

This subsystem is connected to the maintenance and repair subsystem, insofar as materials are used, and is linked to the accounting subsystem and to the suppliers.

The maintenance and repair system presents the information of the material required at an appropriate date at a determined place in the mentioned amount and quality.

The requirements are examined. Is the desired material in stock at the company? Where can it be bought at the best price in an appropriate quality? Depending on the stock situation, the inventory of the materials needed at all locations of the company, and the assessed delivery time the materials are disposed and suppliers are selected. Finally the materials are ordered.

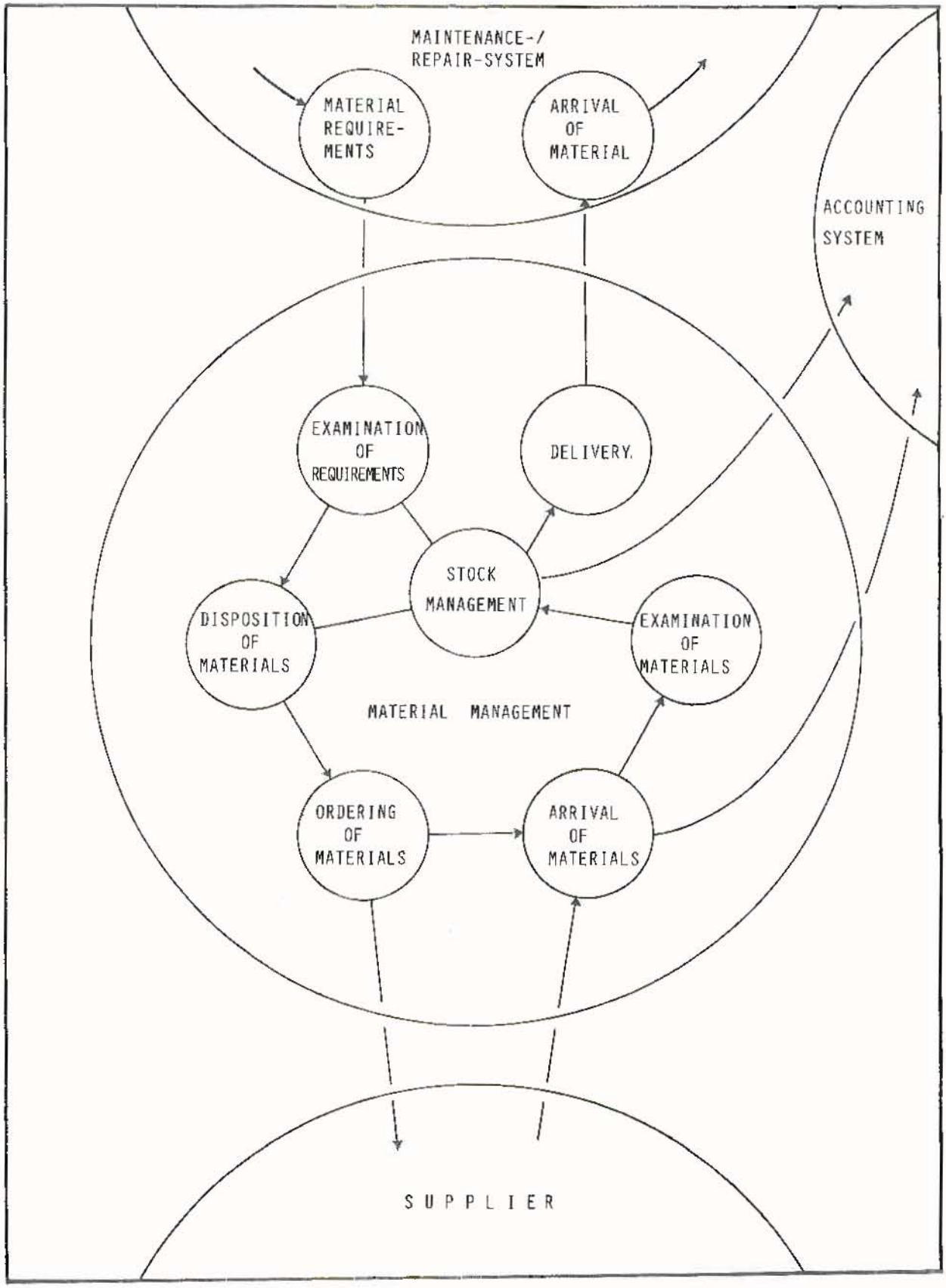

FIGURE 10. Material management subsystem

The delivered material is examined and registered by the stock management. It is then rooted to the different destinations and delivered to the user or stocked centrally.

The stock inventory, the arrival and the delivery of materials are reported to the accounting system.

The nature of the material management subsystem is determined by the large number of different parts (some tens of thousands), the location of stock at different places and the priority of major spares used to repair typical technical equipment such as excavators, dumpers, conveyor belts, etc.

Usual parts are disposed regarding the smoothed amount of parts used in earlier periods.

The basis of the information systems for administrative applications

The information systems for the administrative applications are based on:

Hardware

Central computer systems

Terminals in all departments dealing with administrative applications

Personal computers connected to the central computer systems for undisturbed data collection in processing and conversion plants and for various planning activities

System software

C O D A S Y L-database system, database languages, COBOL, TP-system

Application software

several thousand application programs

dialogue programs for data collection and for the representation of information derived from the data base

batch programs for major management operations and calculations

The integrated database is the heart of the interacting subsystem for administrative applications.

Conclusion

The information needed in a company like Rheinbraun is influenced by external factors and determined by internal changes. Improving the information processing is a never-ending evolutionary process; thus the further development of CALM will integrate interactive graphical work stations and expert systems for various technical and administrative applications. There are already initial expert systems for information analysis and design and for knowledge based information retrieval.