Networking Concepts and Telecommunications

Telecommunication refers to long-distance communication through use of common carriers, including telephone, television and radio.

Data communications is defined as the electronic collection, exchange and processing of data or information including text, pictures, voice and other information that is digitally encoded and intelligible to a variety of machines.

Telecommunications System Components

- Computers to process information
- Terminals or any input/output devices that send or receive data
- Communications processors
- Communications software

![Diagram of telecommunications system components]

**Figure 8-1**

- Front-end processor: Manages communications for the host computer
- Concentrator: Collects and temporarily stores messages
- Controller: Supervises communication traffic
- Multiplexer: Enables single communication channel to carry data transmissions

Functions of Telecommunications systems

- Transmit information
- Establish interface between sender and the receiver
- Route messages along most efficient paths
- Perform elementary processing of information
- Perform editorial tasks on data
- Convert message speed or format
- Control flow of information

TYPES OF TRANSMISSION MEDIA

Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

- Twisted wire:
- Coaxial cable:
- Fiber optics and optical networks

Twisted pair cabling comes in two varieties: shielded and unshielded. Unshielded twisted pair (UTP) is the most popular and is generally the best option for school networks. The quality of UTP may vary from telephone-grade wire to extremely high-speed cable. The cable has four pairs of wires inside the jacket. Each pair is twisted with a different number of twists per inch to help eliminate interference from adjacent pairs and other electrical devices. The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot.

Shielded Twisted Pair (STP) Cable

Although UTP cable is the least expensive cable, it may be susceptible to radio and electrical frequency interference (it should not be too close to electric motors, fluorescent lights, etc.). If you must place cable in environments with lots of potential interference, or if you must place cable in extremely sensitive environments that may be susceptible to the electrical current in the UTP, shielded twisted pair may be the solution. Shielded cables can also help to extend the maximum distance of the cables.

Shielded twisted pair cable is available in three different configurations:
1. Each pair of wires is individually shielded with foil.
2. There is a foil or braid shield inside the jacket covering all wires (as a group).
3. There is a shield around each individual pair, as well as around the entire group of wires (referred to as double shield twisted pair).

**Coaxial Cable**

Coaxial cabling has a single copper conductor at its centre. A plastic layer provides insulation between the center conductor and a braided metal shield. The metal shield helps to block any outside interference from

Although coaxial cabling is difficult to install, it is highly resistant to signal interference. In addition, it can support greater cable lengths between network devices than twisted pair cable.

**Fiber Optic Cable**

Fiber optic cabling consists of a center glass core surrounded by several layers of protective materials. It transmits light rather than electronic signals eliminating the problem of electrical interference. This makes it ideal for certain environments that contain a large amount of electrical interference. It has also made it the standard for connecting networks between

Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair. It also has the capability to carry information at vastly greater speeds. This capacity broadens communication possibilities to include services such as video conferencing and interactive services. The cost of fiber optic cabling is comparable to copper cabling; however, it is
The center core of fiber cables is made from glass or plastic fibers. A plastic coating then cushions the fiber center, and kevlar fibers help to strengthen the cables and prevent breakage. The outer insulating jacket made of teflon or PVC.

Wireless media or unguided media, which is, in a sense, no media at all, is also gaining popularity. Wireless transmissions use radio waves or infrared light to transmit data.

**Radio**
Radio frequency waves often are used for data signaling. Radio frequencies can be transmitted across electrical cables or by using radio broadcast transmission.

**Microwave**
Microwave transmissions can be used for tightly focused transmissions between two points. Microwaves are used to communicate between Earth stations and satellites and they also are used for line-of-sight transmissions on the earth’s surface. In addition, microwaves can be used in low-power forms to broadcast signals from a transmitter to many receivers.

**Infrared**
Infrared light can be transmitted across relatively short distances and can be either beamed between two points or broadcast from one point to many receivers.

**Types of Networks**

**LAN:** (local area network) A group of computers that share a common connection and are usually in a small area or even in the same building. For example an office or home network. They are usually connected by Ethernet cables and have high speed connections. If it was a wireless setup it would be called a WLAN, which would have a lower connection speed.

**MAN:** (metropolitan area network) This is a larger network that connects computer users in a
particular geographic area or region. For example a large university may have a network so large that it may be classified as a MAN. The MAN network usually exist to provide connectivity to local ISPs, cable tv, or large corporations. It is far larger than a LAN and smaller than a WAN. Also large cities like London and Sydney, Australia have metropolitan area networks.

**WAN:** (wide area network) This is the largest network and can interconnect networks throughout the world and is not restricted to a geographical location. The Internet is an example of a worldwide public WAN. Most WANs exist to connect LANs that are not in the same geographical area. This technology is high speed and very expensive to setup.

**Computer Network Topology**

Network topology is one of the very important topics to learn when it comes to build up computer network. There are many Network Topologies on which network administrator decide to build the network on. Topology is basically defined as layout or design of network, and computers are connected using the design of the topology. These topologies can be either physical or logical design. Physical topology refers to physical design of network which includes devices, cables, location and installation of network where as in logical topology it is the amount of data to be transferred with in the network as apposed in its design.

There are five different Networking Topologies :

a) Bus  
b) Star  
c) Ring  
d) Mesh  
e) Tree.

When networks are design using multiple topologies it is called Hybrid Networks, this concept is usually utilized in complex networks were larger number of computer clients are required.

**Bus Topology:**  
Bus topology is one the easiest topologies to install, it does not require lots of cabling. Bus topology based networks works with very limited devices. It performs fine as long as computer count remain with in 12 – 15, problems occurs when number of computer increases. Bus topology uses one common cable (backbone) to connect all devices in the network in linear shape. Network interface cards of all network devices are attached to single communication medium backbone cable. When any computer sends out message in the network it is broadcasted in the entire network but only intended computer accepts the message and process it. Bus topology provide simplicity to the network, however there is big disadvantage of this topology, if main single network cable some how gets damaged, it will shut down the entire network no computer will run on network and no communication can be made among computers until backbone cable is replaced.
Ring Topology:

Ring topology is one of the old ways of building computer network design and it is pretty much obsolete. It is not widely popular in terms of usability but in case if you find it anywhere it will mostly be in schools or office buildings. In ring network topology computers and other networking devices are attached to each other in such a way that they have devices adjacent to each other (Left and right side). All messages are travelled in the same directory either clockwise or anticlockwise. In case of failure of any device or cable the whole network will be down and communication will not be possible.

Star Topology:

This is the most commonly used network topology design you will come across in LAN computer networks. In Star, all computers are connected to central device called hub, router or switches using Unshielded Twisted Pair (UTP) or Shielded Twisted Pair cables. In star topology, we require more connecting devices like routers, cables unlike in bus topology where entire network is supported by single backbone. The most practical point of Star topology success is that the entire network does not go down in case of failure of a computer or cable or device, it will only affect the computer whose wire failed rest of the network will be working fine. However, in case of failure of central communication device such as Hub, Router or Switch the entire network will collapse. Star topology is widely used in homes, offices and in buildings because of its commercial success.
Tree Topology:

Just as name suggest, the network design is little confusing and complex to understand at first but if we have better understanding of Star and Bus topologies then Tree is very simple. Tree topology is basically the mixture of many Star topology designs connected together using bus topology. Devices like Hub can be directly connected to Tree bus and each hub performs as root of a tree of the network devices. Tree topology is very dynamic in nature and it holds potential of expandability of networks far better than other topologies like Bus and Star.

Mesh Topology:

Mesh topology is designed over the concept of routing. Basically it uses router to choose the shortest distance for the destination. In topologies like star, bus etc, message is broadcasted to entire network and only intended computer accepts the message, but in mesh the message is only sent to the destination computer which finds its route itself with the help of router. Internet is based on mesh topology. Routers plays important role in mesh topology, routers are responsible to route the message to its destination address or computer. When every
device is connected to every other device it is known as full mesh topology and if every
device is connected indirectly to each other then it is called partial mesh topology.

MINING SOFTWARE

Gemcom Surpac

Gemcom Surpac™ is the world’s most popular geology and mine planning software,
supporting open pit and underground operations and exploration projects in more than 90
countries. The software delivers efficiency and accuracy through ease-of-use, powerful 3-D
graphics and workflow automation that can be aligned to company-specific processes and
data flows.

Surpac addresses all the requirements of geologists, surveyors, and mining engineers in the
resource sector and is flexible enough to be suitable for every commodity, orebody and
mining method. Its multilingual capabilities allow global companies to support a common
solution across their operations.

Surpac Benefits

- Comprehensive tools include: drill hole data management, geological modelling,
  block modelling, geostatistics, mine design, mine planning, resource estimation, and
  more
- Increased efficiencies within teams result from better sharing of data, skills and
  project knowledge.
- All tasks in Surpac can be automated and aligned to company-specific processes and
data flows.
- Software ease-of-use ensures staff develop an understanding of the system and of
  project data quickly.
- Surpac is modular and easily customised.
• Surpac reduces data duplication by connecting to relational databases and interfacing with common file formats from GIS, CAD and other systems.
• Integrated production scheduling with Gemcom MineSched™.
• Multilingual support: English, Chinese, Russian, Spanish, German and French.

Gemcom Surpac Systems

1. Geological and Resource Modelling

Geologists use Surpac to determine the physical characteristics of a deposit, even when the information available to them is limited. They achieve this by harnessing the system's powerful 3-D graphics, geostatistics, and an integrated modelling environment.

a) Data Management

• Employ sophisticated geological data management tools to store, manage and review drilling data.
• Interface to any popular database product and work in real time while connected to that data.
• View and output sections quickly and easily using drillholes and existing topographic or pre-modelled data.

b) Estimation and Modelling

• Outstanding tools for sample compositing and geostatistics.
• Variogram modelling includes variogram fans and dynamic lag adjustment to help identify the best variograms for data.
• Estimation tools include an interface to GSLIB for both normal kriging and conditional simulation options.
• Comprehensive 3-D wireframing tools enable the development of a truly representative model of any orebody.
• Block modelling tools cover an extensive range of functionality and are easy to use. Validating a model and generating any level of report can be done quickly and efficiently.

2. Mine Planning

Surpac delivers all the tools engineers need to create designs and plans for open pit and underground operations. In the system's integrated mine engineering environment, you can create designs that maximise ore recovery, while complying with project constraints such as cut-off grade, economic limits and ground stability.

• Data from various sources can be viewed and incorporated into plans to support feasibility projects.
• Different pieces of information can be viewed simultaneously to ensure designs are within the physical constraints of the mining area and to maximise the economic extraction of a resource.
• Data can be used directly from other software package formats with Surpac’s sophisticated Data Plug-ins.
• Interact with all mine design data: drillholes; existing orebody and surface models; optimised pit shells; block and grid models, coloured by grade distribution; stope designs, and many more.

3. Mine Production

Surpac provides applications for mining engineers, geologists and mine surveyors that ensure clear plans, effective communication and consistent data utilisation. The software manages drillhole, blasting and survey information, while linking to other databases used at mining operations.

a) Mine Survey and Ore Control

• Calculate and validate volumes quickly.
• Compare kriged models against raw drillhole data to optimise reserve extraction.
• Produce high quality to-scale maps of any relevant project information.
• Road and pit design tools are geared towards surveying setout, ensuring the necessary details required by earth movers are marked out accurately.
• Integrated resource models, pit designs and survey data results in up-to-date ore markouts and dig plans with grade and tonnage reports.

b) Automated Workflows

• Highlight end-of-month reconciliations and reporting problems through the simple automation of comparison reports using Surpac’s macro tools.
• Automate repetitive grade control and plotting tasks using macro functionality, customisable to company-specific processes and data flows.
• Develop new functions using the scripting language embedded within Surpac and assign routines to customised menu bars to better manage workflows.

Mining Case Study: Software Lends a Hand

Straits Resources Ltd. uses Gecom’s Surpac software to manage its precious metals mining, development and exploration business. By Robert W. Selzler

Founded in 1992 and listed on the Australian Stock Exchange in July 1994, Straits Resources Ltd. focuses on acquiring and developing assets in the gold, copper and bulk commodities sectors. Straits is one of the few mining entities based in western Australia with such a well diversified group of assets.

The Perth-based producer controls and operates the Whim Creek and Tritton Copper Operations in Australia and the Mt. Muro Gold Mine and the Sebuku coal mine in Indonesia. In addition, Straits holds an outstanding portfolio of mining investments, development projects and exploration ground throughout Australia and Indonesia. With open pit and underground projects, as well as bulk commodities, Straits required comprehensive technology to use at all of its sites.

Three years ago, Straits spent significant time reviewing several mine planning systems to find an affordable, multidisciplinary approach and a local support network. Straits ultimately
adopted Gemcom’s Surpac software to support resource modeling and mine planning functions.

Today, the company has 30 Surpac installations and uses Gemcom’s training and technical support services. As a result of its investment, Straits has gained more efficiency through decision-making support capabilities, which enables the company to reduce the cost of delivering commodities to the market.

“We have a wide range of projects, so we chose software that applies to all of our mining environments,” says Chris Ramsay, geologist for Straits, who has used the software since 1998. He also notes that Straits engaged with Gemcom to obtain responsive technical support.

**Same Software, Different Functions**

Surpac brings efficiencies, ease of use and flexibility to three mining disciplines at Straits: geology, surveying and engineering. Surpac is the company’s primary data manipulation, resource modeling and estimation, volume calculation and grade-control system.

By employing Surpac, Straits has significantly increased the resource base at all of its operations: Straits surveyors use Surpac for volume calculation, and the company’s engineers count on Surpac to provide 3-D designs and calculations, as well as to manage grade control and resource inventories.

The software conveys information to them in visual ways that enhance non-mining professionals’ understanding of mining operations.

“Without Surpac, our work would take longer, and we would need dozens of extra people in my area alone,” Ramsay says. “To a lesser extent, the engineering and surveying areas would also need to hire additional staff.”

**Better Decision-Making**

Although other, competitive systems are available, Ramsay says that Surpac’s 3-D visualization of ore body and block models is helpful to Straits’s geologists who create models to bring about multibillion-dollar results and make wise decisions about Straits’ mining operations.

“We gather sparse information that is very expensive to come by,” he says, “and the representation of that spatially is critical in correctly calculating what is in the ground. Surpac gives us a strong comfort level that we are making the right decisions to achieve high-value results.”

**A Wealth of Features**

Surpac is integrated with the company’s 16 GIS and 3-D mining applications, and package translations are available at the touch of a button. When needed, the software’s language options, including English, French, Spanish, Chinese and Russian, enhance collaborations at Straits’ locations globally.
Alternative sources of data convert well into a Surpac readable file. In fact, Straits’ teams are able to view data from various IT systems with the software’s Data Plug-in modules, and incorporate this information into their planning.

“In any of the packages that we have, we transfer geographic or 3-D information back and forth into Surpac very easily,” Ramsay says. “Surpac’s representation of geographic information in a text file is extremely simple.”

It is also a simple exercise to program certain management processes using the software’s scripting/macro capabilities. “We gain a lot of power from the scripting/macro,” Ramsay says.

In addition, the Gemcom software instantly includes information from other core data systems. Plus, the company can leverage the most current information to save operational costs. “In some of the mining operations, we might spend from $50 to $500,000 a day, so instantaneous refining of information is critical to cost savings,” Ramsay notes.

Straits’ growth has prompted it to expand Surpac usage as its work force increases for a particular project. Implementing another system into an active environment is as simple and quick as copying files onto the company’s work station.

“With Gemcom as our partner, we see being able to expand our solution as our operations needs change in the organization,” Ramsay says. “Gemcom provides a greater level of funding and programming support behind this product. However, right now, we’re quite happy with Surpac.”

In establishing Surpac software as its standard technical tool, Straits empowers its personnel to share data, skills and project knowledge across the company in a consistent way. “At our Perth headquarters, we have one format for dealing with any information that comes in centrally,” Ramsay says. “This also enables us to manage training in a collective way.”

Straits takes advantage of Gemcom’s base of trainers, selected for their in-depth mining knowledge and industry experience. In addition, the company’s technical support services play an important role in Strait’s decision to continue with Surpac. As a shortage of skilled workers continues to plague the resources industry, Straits commands a competitive edge in the labor market, stemming in part from its use of Surpac. “Because Surpac has a fair share of the industry in this region, attracting skilled practitioners to Straits is somewhat easier,” Ramsay concludes.

**QMASTOR**

features:
- Ore tracking and stockpile management at mine
- Recording truck dispatch movements
- Tracking of waste and rock movements
- Management of Feed Preparation Plant
- Integration with Labware (LIMS)
- French user interfaces
- Comprehensive web based reporting

**QMOSTOR Products**
1. Pit to Port: Management information system for companies operating export and/or domestic bulk materials supply chains

2. QMASTOR PortVu: Integrated bulk terminal management system enabling controlled visibility of terminal operations for all relevant stakeholders

3. Pit to Plant: Supply chain management information system for companies producing and consuming bulk materials domestically

4. Port to Plant: Supply chain management information system for companies who import bulk materials or those with a supply chain originating at a Port

5. SMS3D: Three dimensional stockpile modelling & management system

6. Horizon: Advanced Planning & Scheduling (APS) system for the mining and related industries operating complex bulk material supply chains

7. iFuse: Integrating mining, business & bulk commodity information systems

8. QMetrics: Performance management platform for mines, ports and utilities to harness the power of information and improve operational performance

SimMine
SimMine® is a business improvement tool for the mining industry. By using SimMine as the method for verification, you will get far more accurate results than with common spreadsheet based programs. SimMine can be used both for existing and future mines.

The SimMine product family consists of many different simulation products, all designed to help mining companies make more correct choices when it comes to decision making.

1. Underground development simulation software
Allows users to make the most out of their assets by using SimMine for optimised resource planning and scheduling of underground development. SimMine helps in assuring that your development project is completed on time and within budget. The SimMine development package is easy-to-use and powerful software to plan, simulate and evaluate the development process in underground mining. SimMine can be used both for existing and future mines.

The SimMine development package contains:

- Gantt-scheduler for easy-to-use and perceptible planning
- Simulation core for verification of development plans
- SimStat function for optimization of development plans
- Plan, time, capacity and cost reports
• 3D environment for import of existing mine designs
• Visual feedback through animation of development progression and equipment movement

The SimMine development package improves development processes by allowing the user to:

• Test long and short-term schedules ahead of time to see if development targets can be met
• Compare different scenarios to yield an improved development schedule
• Find the optimal fleet size and shift schedule
• Reduce bottlenecks and equipment conflicts
• Watch ongoing operations animated on the screen to validate equipment assignments
• Analyse multiple infrastructure scenarios
• Simulate drift development with both single and multiple headings for long access drive

2. Mining simulation program

A mine's infrastructure changes over time as development advances. It is difficult to predict the long-term logistical consequences of decisions made today. By simulating different long-term plans, the best strategy can be chosen for each unique situation. The mine's engineers can use simulations to test a plan's strengths and weaknesses in order to evaluate the likelihood of achieving the set goals.

By using simulation software, every aspect of a proposed change can be analysed without investing resources on implementation. This is crucial, because, when the decision has been made, the concrete is in place, or the transport system is completed, changes or additions are very costly.

3. Machine, truck and haulage simulation

Simulation can be used to specify requirements for the design of a system. For example, the specific requirements for a machine in a complex production environment might not be known. By simulating different performance levels for the machine, the requirement level can be set. Bottlenecks in production are a headache in the industry. It's easy to forget that bottlenecks are an effect, rather than a cause.

One of the advantages of simulation is that policies, control criteria, procedures and methods can be analysed when a valid model has been set up without disrupting the actual system. Changes can be introduced in the model, and the effects happen on the computer, instead of in the actual system.

4. Short term planning

It provides shift schedules for development crew, what section they will work on and with what vehicle. It also gives the user ability to quickly reschedule/simulate the schedule if something happens that will affect the original schedule. To see how these changes will affect your long term plan you can export these changes back to SimMine for simulating long term effects on your plan.
APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO THE PRODUCTION AND POST-PRODUCTION PHASES OF A MINE

Definition of GIS

Geographic Information Systems, or GIS software packages combine the power of database management systems (DBMS) with the benefits of computer-aided drafting and design (CADD) software, to create a versatile new way of managing and analyzing data.

How does a GIS differ from CADD and database management software

GIS is combines the capabilities of computerized mapping software and database management and analysis software. Most GIS packages do so by first characterizing and recording all spatial phenomena as points, lines, or polygons in space. Examples of points might include monitoring wells, electricity poles, and spot elevations, while examples of lines might include roads, streams, and contours. Polygons might include soil groups, parcels of land, or the extent of waste rock disposal areas.

In GIS the location of each feature is recorded in the computer as a series of coordinates in some recognized coordinate system and a standard map projection. Then, after each feature is recorded, GIS permits users to attach any amount of information about that feature in a linked database. For each stored land parcel can be recorded its owner's name, address, and telephone number, each lessee's and lessor's relevant information, the assessed value of the land, the governing jurisdiction, and so on. Each groundwater monitoring well can have attached to it historical records of all the chemical constituents of water samples, their temperatures, pH factors, and depths below the surface.

This first attempt to define GIS should obviate the distinct differences between stand-alone CADD or database management software packages and GIS. Neither type of software can effectively store and display both tabular and graphical data. A GIS, on the other hand, can easily display maps based on the pre-selection of tabular data, such as displaying a map of all the mineral ownership leases about to expire in the next six months, or a map that shows all the monitoring wells whose cyanide content has exceeded acceptable levels in the past month. Likewise, a GIS enables users to select which parcels of land need to be leased or purchased based on their exact distance from a new mine or from a new planned access road.

A second important aspect of GIS, which can only be duplicated in a very primitive way with mere database management systems, is the ability to overlay different layers, or themes, of spatial data in order to analyze the relationships between them. For example, consider the effort required to produce a new map which depicts all areas around an existing processing mill which are: a) within 300 foot elevation difference from the elevation of the mill; b) overlying impermeable soils; c) are away from known faults; and d) are owned by the owners of the mill. Such a map, which might be required in order to site a new tailing facility, for example, might take days if not weeks to produce by manual methods or even using CADD. The level of effort is vastly increased if the source maps come in a typical assortment of sizes
and scales. Once this data is entered into a GIS, however, such a task can take as little as a few minutes. Better yet, the criteria used to produce this map can very easily be changed (e.g. a 400 foot elevation difference), and a new map created.

To extend this example further, suppose that the land required for the new facility and for access roads may be purchased or leased by the owners, if it does not already belong to it. Prior to GIS, comparing the total costs of construction versus land acquisition would have required complicated computations based on the use of a planimeter or CADD tools to measure the amount of land involved with each scenario. If the various possible locations of the new tailing are drafted into a GIS, though, those computations can be performed in a manner of minutes. And whether the measurements are made by one operator or another, they will remain the same, because they are not based on human interpretation, but rather on actual real world coordinates.

One of the attributes that can be assigned to geographical features is elevation. Therefore, most GIS packages have the capability to generate three-dimensional surface models and compute volumes. This capability is not unique to GIS. In fact there are powerful packages available that do little else but compute surfaces and volumes. The advantage of incorporating these capabilities into GIS is that the data that are used to generate these surfaces and volumes can be selected interactively from a computerized map, and that the results of such analyses can be translated back into maps, or integrated with other GIS layers. For example, a GIS database may contain contour information, spot elevations, seismic surveys which indicate the depth to bedrock, and borehole information also indicating depth to bedrock. Computing the volume of soil and loose aggregate available for excavation, as an example, requires the "development" of a three dimensional surface for the ground surface, and one for the bedrock surface, before volumetric computations can be made. Since not all depth and elevation data are of equal precision and reliability, GIS can be used to interactively select the data points used to create these surfaces, until the best possible surfaces are generated. Likewise, the results of the computations can be easily translated back into two-dimensional maps depicting the areas which will actually be excavated.

Two methods have been discussed so far by which GIS can view spatial data: as points, lines, and polygons, and as three-dimensional surfaces. An increasing number of packages also offer the option of viewing spatial phenomena in a grid-cell, or "raster", format, in which the "world" (at least that portion of the world considered in a particular database), is divided into a grid of equally shaped cells. Each cell is then coded with a single primary code, depending on the theme of the map. For example, in a soils map, a cell will be coded as either clay or sand, but never both. This particular method of representing spatial data is especially well suited for modeling environmental data. For example, drainage basins have automatically been delineated and the plumes of pollution in groundwater have been studied with this method.

GIS can represent the same spatial data in a variety of ways, each with its pros and cons in terms of the type of analysis and mapping that it is best suited to produce. But regardless of the method of storage, GIS data are stored in real world coordinates. Some of the benefits of this feature are that data from a variety of sources and in a variety of scales can easily be integrated with each other and compared for compatibility. A by-product of GIS spatial data handling capabilities is its strong ability to aid in quality controlling data. Two adjacent paper vegetation maps, for example, may give no indication of incompatibility. However, once digitized into a GIS, placed in the same coordinate system, and then superimposed on each
other, even slight positional mismatches can easily be detected, which may prevent costly errors in the future. Also due to the fact that GIS data are stored in real world coordinates, the concept of scale (other than of the original source data), does not exist. This means that no restrictions exist on the scale at which data are viewed or plotted. A dozen adjacent map sheets, which may be difficult to view as a single entity in paper format or in a CADD system can be easily displayed in a GIS. As a side note to the issue of scale, unlike CADD, GIS annotations are not tied to a particular map. Therefore, whether zoomed in or zoomed out on a particular map, the text does not enlarge or reduce, but rather remains the same size as the one specified by the operator for that map.

The advantages of storing spatial data as real-world coordinates cannot be overemphasized. This feature enables GIS to easily translate data between various projections and coordinate systems, thereby making GIS a powerful data integration tool. A single GIS database might contain layers that have been digitized from paper maps, digitally converted from CADD drawings, automatically generated from spreadsheets (which contain coordinate data), scanned from documents, captured by remote sensing devices on satellites, or photographed from an airplane. This ability alone can sometimes justify the use of GIS, even if the GIS is not asked to perform any analysis with these data.

Having so defined GIS, it is important to clarify what exactly GIS is not. GIS is not synonymous with CADD. CADD software packages are designed specifically to handle any graphical data (not just spatial data), and to perform analysis with them which are often far from spatial analysis (material and structural performance, mechanical motion modeling, and systems control are examples that come to mind). Nor are graphical data usually stored in real world coordinates in a CADD system. Rather they are stored in the units in which they will be plotted on paper, or multiples of these units. Thus a CADD operator is really always manipulating the final plot on the computer, and then sending it to the plotter. A GIS operator, on the other hand, is usually working with simple graphical representations of spatial phenomena in real world coordinates on the screen, and only translates these into appealing maps and plots just before submitting them to the plotter. Thus colors, patterns, annotations, and other graphical communication tools are not a part of the database, but of the cartographic process associated with turning spatial database layers into maps.

GIS is also not synonymous with graphics or desktop publishing software. These packages too are concerned with the final plot, and the operator, very often an artist, manipulates the digital representation of the final plot at all times. Thus, although maps and plots produced by GIS may often appear beautiful or artistic, GIS is not an artistic software.

Fortunately, GIS packages usually come supplied with a variety of data translation tools which enable them to exchange data with CADD, graphics, desktop publishing, spreadsheet, database management, and word processing software. Such terms as DXF, TIFF, BIP, CGM, ASCII, and IGES are frequently used in conjunction with discussions of data exchange. Thus aerial photography, for example, can be photogrammetrically converted into contour maps using digital photogrammetry devices, then enhanced or manipulated in CADD, analyzed in GIS, and included in a report produced with a word processing software. Although this process may sound more convoluted than most firms or agencies might wish to engage in, the process described above is an extreme example, but one which is nevertheless viable, and which can yield substantial benefits, especially when associated with repetitive operations.
The aspect of repeated actions is key to the benefits of GIS. As with many software
technologies, GIS can yield substantial benefits as outlined above, due to its unique tools and
method of viewing spatial phenomena. Where GIS truly benefits its users, however, is in
automating repetitive processes. GIS packages usually fall under the "toolbox" classification
of software. Which means that they contain various commands that enable users to perform
discreet actions, which if strung together in a logical progression enable users to execute a
task. In this aspect GIS is similar to word processing. Word processing software contains
tools to enter, erase, and move words, to center paragraphs, and make text appear bold or
italic. Word processing software, however, does not write letters, books, or reports. People
do. This too is the case with GIS. The difference between the two, though, is that GIS can be
trained to perform the same actions with different data with the aid of macro programs. In
this way GIS can be customized so that it can be used by engineers, scientists, and managers,
rather than by GIS specialists alone. Thus, for example, a GIS specialist will be required to
use the GIS tools that select land parcels by value, that create all the elements of a map, that
insert the desired parcels into the map, that generate a report relating to the value of the
surrounding parcels, and that place that report on the map. However, if this action needs to be
performed on a repeated basis for various parcels, or with updated assessed values, then the
GIS can be customized to perform that "application" in a simple, user-friendly fashion, so
that the actual user of the data, such as a manager, can with no more that a few key-strokes
ask the GIS to generate that map. This places powerful tools in the hands of the professionals
who need them most. In the sections that follow, several examples of GIS applications are
given as they relate to the processing of a mine's output, the disposal of its wastes, and the
ultimate remediation of the mine site itself.

Applications of GIS to the production phase of a mine

1. Site selection

GIS can be used to select a new site for a waste rock disposal area or a tailing facility, where
various thematic layers are first manipulated singularly (e.g. selecting alternative elevations
from the topography layer), and then combined by overlaying them on each other. This
methodology can also be applied to siting such things as new roads. In addition to overlaying
layers of information, GIS can also be queried for the distance between various features, their
areas and volumes. Thus, once potential sites for a tailing facility are identified, the volume to
surface area ratio of the sites can be computed and compared. Also, buffers can be created
around selected features, such as ecologically sensitive areas, to identify zones of no
interference. Other GIS tools which can be brought to bear in the process are the ability to
compute the slope angle and direction of the surface, and the ability to compute the inter-
visibility between points. Potential objections to the expansion of a facility based on the
visual impact of the construction on a nearby resort, for example, can be eliminated by
determining that the expansion (e.g. a tall stack) will not be visible from the resort. Other
factors which play into the processing of site selection such as property ownership, lease
holding, and mineral rights, can also be successfully managed within a GIS database.

2. Environmental Quality Monitoring
The integration environmental quality indicators such as water and air pollution levels data into a GIS enables the analyst to query monitoring locations on digital maps, as well as to display the results of spreadsheet or database type queries on a map. It also permits the creation of interpolated surfaces or plumes, indicating the rising and falling levels of the pollutants through space. Such horizontal slices across the data can be stored as snapshots in time, and then displayed in sequence to help identify trends which might indicate the spreading of a plume. This particularly applies to water-borne pollutants. Air-borne pollutant analysis can benefit from GIS by overlaying interpolated plumes on layers showing concentrations and characteristics of human populations. This can be used to assess risk and in certain cases enable an appropriate and rapid response to emergency situations. In either case, GIS can also be helpful in predicting where and when various pollution levels might exceed permissible levels, which can mitigate costly remediation activities under emergency situations.

3. Volume Computations

Assuming that a topography layer was created in a GIS prior to the commencement of production, GIS can be used to compute the increasing volumes of waste rock heaps, and in the case of open-pit excavations, the volumes removed. This is done with periodic flights over the mine site, and the photogrammetric conversion of the resulting photographs into new layers, which when compared to older layers using the volumetric tools of the GIS, yield the volume differences between the old and new layers.

Applications of GIS to the post-production phase of a mine

1. Vegetation Characterization

The remediation of an old mine site can take several forms. These include the returning of the site to a state that most closely resembles the original lay and appearance of the site prior to development, as well as the conversion of the site to a new appearance and use, as in turning an old rock quarry into a recreational lake. When a site is to be returned to as close to a natural state as is possible, it is preferable to obtain a careful record of the local biomes, preferably prior to the development of the site. Since this is usually not possible, it is important to characterize the surrounding vegetation and wildlife, so as to best predict which remediation plan to embark upon. For example, it is important to match vegetation and top soil not only to the slope of the reclaimed land, but also to its aspect. It is a fact that vegetation zones (e.g. deciduous forest, alpine meadows, etc.) occur at lower elevations on north facing slopes than they do on south facing ones. Therefore, an attempt to plant vegetation of the same type at the same elevation on both sides of a valley may prove troublesome. GIS is ideal for storing and analyzing vegetation and wildlife characteristics.

Slope-Aspect Characterization

In addition to determining the correct biome based on the slope and aspect of the land, as explained above, slope and aspect characteristics also indicate the levels of erosion control efforts required at any particular portion of a site. Slope and aspect calculations are direct derivatives of the surface modeling tools built into most GIS packages. Coincidentally, these two characteristics have been used in GIS to determine the amount of insolation (duration and
intensity of sunlight), which are also important determinants in the success or failure of any particular remediation plan. Occasionally slope and aspect are important when planning a new use for an old mine site. For example, a recreational lake is of limited use if accessing the lake poses dangers due to steepness or surface instability.

2. Volume Computations

No less important in the post-production phase as in the production phase, the ability to compute volumes is essential to a good remediation plan. Most remediation plans require considerable volumes of soil to be moved, and where these can be obtained locally, the cost of remediation is reduced. Thus it is important to determine the amounts of soil which are available for removal nearby. This also applies if concavities need to be filled in with crushed rock, or if quarries need to be filled in with water.

3. Visualization

One of the more important aspects of site remediation planning is becoming the process of "selling" the plan to the governing bodies as well as to the public, and this is more and more frequently done with the aid of visualization tools. To be convinced, people wish to see what the planned remediation will look like when it is complete. By itself, GIS can produce impressive visual simulations of proposed remediation plans. Together with graphics packages the results can be truly astounding, and can often make very strong statements in and of themselves.

Implementation of GIS

It is worth noting that implementation of GIS comprises of many interrelated hardware and software components. Hardware can consist of as little as a mid-powered PC to a very high powered engineering workstation (UNIX being the most popular operating system for such). Fully configured GIS shops, however, also include large format digitizing boards, color plotters (pen-based or electrostatic), printers, various computer peripherals such as tape backup devices, and occasionally scanners and other esoteric equipment.

ArcInfo

ArcInfo is the most complete desktop GIS. It includes all the functionality of ArcEditor and ArcView and adds advanced spatial analysis, extensive data manipulation, and high-end cartography tools. Organizations use the power of ArcInfo every day to create, edit, and analyze their data in order to make better decisions, faster. ArcInfo is the de facto standard for GIS.

With ArcInfo, you can

- Perform advanced GIS data analysis and modeling.
- Take advantage of tools designed for overlay analysis, proximity analysis, surface analysis, and raster processing and conversion.
- Publish and convert data in many formats.
- Create and manage personal geodatabases, multiuser geodatabases, and feature datasets.
- Use high-end cartography tools to generate professional-quality, publication-ready maps.
- Design customized symbols and place sophisticated annotation and labels on your maps.

The key features of ArcInfo are

1. **Advanced spatial analysis and modeling**—Select from hundreds of geoprocessing tools to perform advanced GIS data analysis and modeling.
   - Perform overlay analysis including Union, Intersect, and Erase.
   - Perform proximity analysis including Buffer, Near, and Point Distance.
   - Perform surface analysis including Aspect, Hillshade, and Slope.
   - Perform raster processing and conversion.

2. **Extensive database management**—Create and manage databases, define database schemas, and administer the integrity of databases.
   - Create personal geodatabases, multiuser geodatabases, and feature datasets.
   - Apply spatial analysis functions to transfer data into and out of databases.
   - Publish data in many formats.
   - Join adjacent datasets.
   - Perform batch processes on your databases.

3. **High-end cartography**—Create professional-quality, publication-ready maps with simple wizards, predefined map templates, an extensive suite of map elements, and advanced drawing and symbolization tools.
   - Apply cartographic text and labeling for atlaslike, publication-quality maps.
   - Design customized symbols, thematic categories, and style sheets for your map products.
   - Reduce manual editing time using intelligent rule-based annotation and label placement.
   - Use the functionality of the Maplex for ArcGIS extension (included with ArcInfo) for sophisticated annotation and label placement.

4. **Enabled for extensions**—Add even more capabilities and extend the power of ArcInfo by using one or more of the many optional ArcGIS Desktop extensions. Analysis, productivity, and solution-based extensions allow you to perform extended tasks such as raster geoprocessing and three-dimensional analysis.

**Applications of OR in mining**

1. **Economic Evaluation**
   Few activities are as uncertain as mining. The initial ore body is usually indicated by a number of drill holes whose intersection with the body is used to estimate both the uncertain amount of ore present and its uncertain grade. The initial mine development usually requires
a substantial initial investment not only in plant and equipment but also in the initial development of the mine to the point that the ore can begin to be produced. Finally minerals are commodities and as such subject to enormous price fluctuations in the commodity markets. To top this off, most mineral sales are denominated in US dollars and currency fluctuations can have important implications for Canadian mining companies. Together with a regulatory environment that is constantly changing, this results in one of the most challenging decision environments one can imagine. As a result mining decision makers have tended to rely on conservative economic decision criteria such as payback period or requiring relatively high internal rates of return. However, one of the challenges is that modern mining regulations require a reconfiguration of the mine site to something like its original condition at the end of the mine life. This implies that the investment must be a non-conventional mixed investment.

2. Mine Planning for Open Pit Mining
A basic problem of open pit mine planning is planning the ultimate contours of the pit. The region to be mined is represented as a set of 3 dimensional blocks where each block has a given ore percentage. Each block has a given objective function value for removal, which can be negative for blocks having low ore values. There is a precedence relationship that specifies which blocks must be removed before a given block can be removed. Typically this requires that at least the block directly above the given block and blocks adjacent to the block above the given block must be removed before that given block can be removed. The classic paper on this problem was written by Lerchs and Grossman. (Jorgen Elbrond informs me that this paper was first presented at a CORS Conference held in Montreal.) They showed that the optimum pit corresponds to a maximal closure in the mine graph which corresponds to the above mentioned precedence relation. Picard showed that this problem could be solved as a maximum flow problem. Picard and Smith have explored this solution concept in more detail. This classical open pit design problem is essentially static. It does however establish pit limits and to a certain extent indicates the blocks that will not be mined. The next stage is to determine not only which blocks should be mined but when they should be mined. Mill and other capacity constraints limit the amount that can be mined in a period. Dagdaleen developed an integer programming formulation of this problem and developed a solution procedure using Lagrangian relaxation and decomposition. Tachefine, Soumis and Vanderstraten have also developed a Lagrangian relaxation approach and showed that the subproblems can be solved as maximal flow problems.

3. Operational and Production Planning
Operational planning in mining usually combines some aspects of blending the ore produced to achieve some sort of quality requirement while at the same time attempting to minimize costs of production. These costs of production usually involve not only direct costs of ore removal but also transportation to various processing facilities. Lestage, Mottola, Scherrer and Soumis discuss a situation where a dynamic programming technique is used to look at scheduling drilling and blasting and shovel displacements and utilization. Soumis and Elbrond look at the problem of dispatching trucks to shovels and routing to crushers to both minimize trucking costs and achieve a suitable ore feed to the crushers. Some operational planning problems can involve combining material from several mines. Gunn and Rutherford discuss a combined system of a tactical linear programming production planning model together with a short term operational decision support to plan the allocation of coal from several mines to meet the requirements of several classes of customers.

Capacity Planning
Models of capacity are usually at the upper level of hierarchical planning processes. However, in mining, the capacity determines the rate of extraction and hence exhaustion of the reserve. Thus there is usually an interaction between the capacity decision and the production decisions. Lizotte and Elbrond have looked at the choice of mine-mill capacities using dynamic programming methods. Gunn, Cunningham and Forrester looked at optimal coal mine capacity decisions in the context of the market requirements for various grades of coal products. This dynamic programming approach uses a linear programming subproblem at each node to calculate coal allocation and blending to maximize profit for the given capacity state.