technology innovation
AGENCY

The Mining Sector Innovation Strategies Implementation Plan

2012/13 – 2016/17

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Executive Summary

South Africa's economic growth has been and will continue to be closely linked to the fortunes of the mining industry. The country is one of the world's most important mining countries in terms of the variety and quantity of minerals produced. The total mineral endowment in South Africa was estimated at US$4.71 trillion while the country has been identified as the world’s richest in terms of its non-energy mineral reserves which are worth an estimated US$2.5 trillion. It has the world's largest reserves of Platinum Group Minerals (PGM's), chrome, gold, vanadium and manganese. It is also ranked first for the production of PGMs, manganese, chrome and vanadium, second for zirconium and titanium production, and third for gold.

The mining industry is also the third largest sector in the South African economy after the agriculture and industrial manufacturing sectors. It accounts for approximately 8% of GDP[1] and creates approximately one million jobs (500 000 direct and 500 000 indirect). The importance of the sector to the South African economy necessitates that its various role players within their respective mandates, enhance its competitiveness.

The development of new technologies benefits every major component of the mineral industry, including exploration, mining, mineral processing, beneficiation, associated health and safety issues, and environmental issues. Therefore, technology development needs to be focused on those areas that are critical to the entire value chain.

The purpose of this document is to define the strategy for TIA’s initiatives in the mining sector. The overall objectives are defined as:

- Efficient, Safe and Competitive Production: Use advanced technologies to improve process efficiencies from exploration to final product and reduce worker exposure to hazards as well as maintain a competitive mining sector.
- Environmental and Health Management: Support the development of technologies to minimise the impact from mining activities on its workforce, the environment and the community.
- Minerals Upgrading and Value addition: Support the upgrading and value addition of South Africa’s minerals, also by encouraging local manufacturing and production.
- Lateral migration: Exploit the knowledge and capacity in the mining sector to create new high-value economic sectors.
- Innovation culture through skills development: Build an innovation culture through leadership, skills and support infrastructure.

For each of these goals, key priorities have been defined in the document.

[1] Gross Domestic Product

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1.0 Introduction

South Africa's economic growth has been and will continue to be closely linked to the mining industry. The country is one of the world's most important mining countries in terms of the variety and quantity of minerals produced. According to a Citigroup 2010 research report[2], South Africa is the world's richest country in terms of its non-energy mineral reserves, worth an estimated $2.5 trillion while EcoPartners estimates the country's total in situ resources at US$4.71 trillion[3]. South Africa has the world's largest reserves of Platinum Group Minerals (PGM's), chrome, gold, vanadium and manganese. South Africa is also ranked first for the production of PGMs, manganese, chrome and vanadium; second for zirconium and titanium production; and third for gold production.

Furthermore, the mining industry is the third largest sector in the South African economy after the agriculture and industrial manufacturing sectors. It accounts for approximately 8% of Gross Domestic Product (GDP) and creates approximately one million jobs (500 000 direct and 500 000 indirect). The importance of the sector to the South African economy necessitate that its role players within their respective mandates, enhance the mining industry's competitiveness.

In general the development of new technologies benefits the competitiveness of any economic sector. The mining and minerals sector is no exception and every major component of the sector, including exploration, mining, mineral processing, mineral value addition (beneficiation), health and safety issues, and environmental issues would benefit from technology development. The sector strategy recommends that collaborative technology development should form part of the interventions to improve the competitiveness of the sector and focus on technology areas critical (cross-cutting) for all areas of the value chain.

This document outlines TIA's innovation strategic plan for the mining and minerals sector portfolio for the period 2012 to 2016. The five-year plan takes into account the following:-

- the state of research and development in the sector,
- stakeholder needs and requirements;
- mining industry opportunities and challenges, and
- emerging technologies.

The main thrust of TIA's strategy is <u>*to enhance innovation*</u> with the ultimate goal of economic growth through the development of ***new products***, ***services*** and ***companies***.

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[2] 2010 research report prepared by Craig Sainsbury of Citi Investment Research & Analysis - a division of Citigroup Global Markets Inc.

[3] Available at www.kwikwap.co.za/ecopartners/docs/Mineral%20Resource%20and%20Reserves%20of%20South%20Africa.pdf

2.0 Sector Overview

Mining involves the full life cycle from exploration through to production (mining and minerals processing) up to closure and rehabilitation. Mining remains a controversial subject, because while it creates jobs and spurs economic activity, it inherently has an adverse impact on the environment. Modern civilization has consistently grown dependent on mining for its survival needs and this is not projected to change in the near future. Modern mining methods have become increasingly safer and many government regulations are designed to ensure that mining activities are managed to mitigate their impact on the environment.

The development of new technologies is targeted at extracting incremental benefits from specific components of the mineral industry value chain. These include exploration, mining, mineral processing, beneficiation, associated health and safety issues, environmental issues, post mining operations, and social and labour plans to mitigate against the phenomenon of 'ghost towns'.

Within the TIA context the sector includes the areas as defined below.

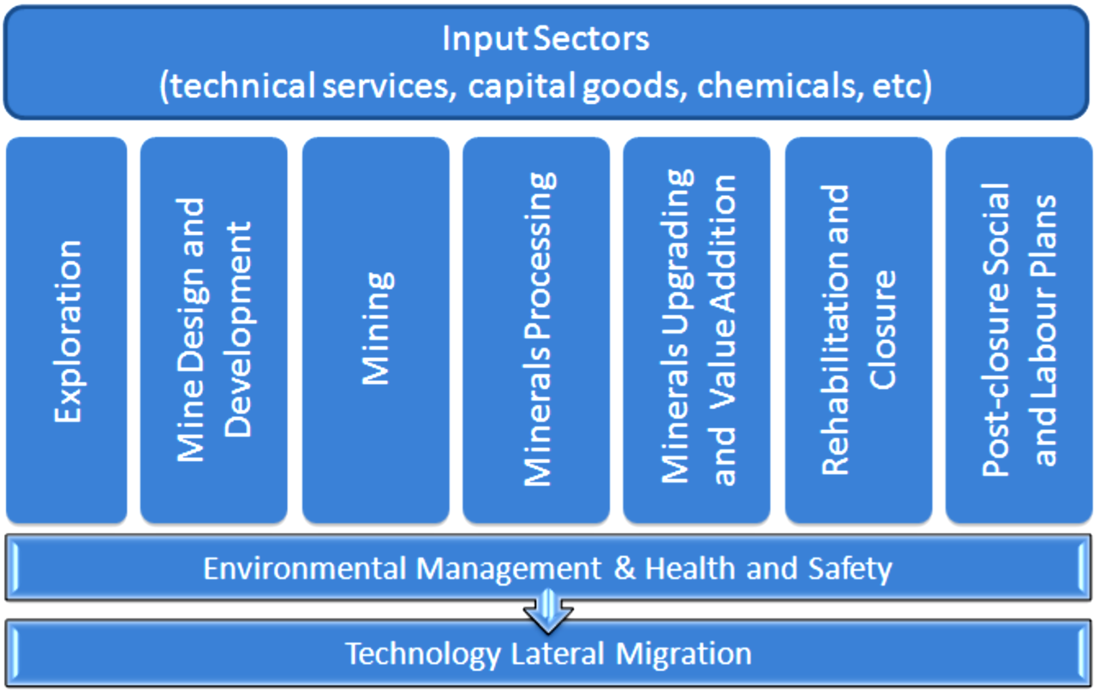

Figure: 1 Mining and minerals sub-sector view

It is recommended that technology development be focused on technology areas critical for all the areas outlined as part of the value chain.

2.1 MINING AND MINERALS SECTOR VALUE CHAIN

2.1.1 Exploration

Mineral exploration is the first step in the mining process, which involves locating a commercially viable concentration of minerals. Techniques from various disciplines such as basin modelling, structural geology, geochronology, etc. are applied to a selected area followed by target generation, which involves investigations of the geology by mapping, geophysics, geochemical analysis and sometimes drilling. Aerial photography and satellite imagery are used extensively to generate high quality maps. Geophysical surveys are very important in gathering geological data and sense variations in gravity, magnetism, electromagnetism (conductivity and resistivity of rocks) and other variables.

After target generation and prioritization, the viability of individual targets is investigated through drilling conducted in collaboration with market studies. Thereafter, resource evaluation, reserve definition and feasibility studies are completed. The purpose of this exercise is to generate increasing degrees of confidence in the information that provides a substantiated techno-economic feasibility study which confirms the economic value, if any, of an ore deposit.

Successful performance in mineral exploration requires inter alia recognition and support of the applied geosciences as a knowledge-based industry of geology. This requires skills and transfer of knowledge related to observation of rocks, compilation of maps and generation of models. Capacity exists in the service industry to develop innovative technologies in geology. Higher education institutions need to maintain and further develop teaching and research in exploration geology. Business and higher education institutions need to collaborate in this regard.

In general, deposits that are exposed on the surface are relatively easy to discover and recover. In many parts of South Africa, such as the Kalahari, surface cover conceals potential deeper deposits. Research and development is required to improve the ability of geophysical tools to more accurately map geology below cover, in order to make new discoveries possible.

2.1.2 Mine Design and Development

The mine development phase determines if a deposit can be mined economically. This phase includes technical assessments, development of mine plans and infrastructure, fulfilment of all the necessary regulatory requirements, impact assessments, final project evaluation, construction and commissioning of the mine. Again, capacity exists in the service sector to support all stages of the process. *<u>Increased innovation in this phase would markedly lower investment and production costs and reduces the time from planning to mine commissioning</u>*. Once an ore deposit is deemed economic, and all the requisite permits, licences and rights have been applied for and granted, then mine development occurs to access the ore body with associated infrastructure construction and equipment procurement. Mine buildings and processing plants are constructed and recovery of the ore begins.

2.1.3 Mining

Mining is the process of extraction of valuable minerals from the earth or from an ore body. Mining techniques can be divided into two common categories: surface mining (also known as open cast) and underground mining. The type of technique used depends on the (geology of the deposit) type of mineral and other mineral occurrence characteristics. Most South African mineral resources are found in deep mines and 75% of mining operations use underground mining methods. These deep mines are technically more complex to exploit and economically mineable resource decreases as the depth increases due to safety considerations. Furthermore, much of the mineral potential is located at great depths where complex geo-mechanical and thermal conditions make their safe extraction more challenging. Mineral potential, combined with current and forecasted shortage of highly qualified personnel require the mining sector to innovate and to improve the mining methods currently in use to maintain a safe, environmentally sustainable and competitive mining industry.

2.1.4 Minerals Processing

Mineral processing and extractive metallurgy are devoted to the scientific, engineering, and economic aspects of the extraction, preparation, separation, and purification of ores, metals, and mineral products by physical, chemical, pyro metallurgical, hydro metallurgical, magnetic and biological (e.g. microbes) methods.

The recent economic boom in the fast developing countries (China and India being such examples) has resulted in a sharp increase in the demand for minerals and metals. As the world's more viable deposits deplete, there will be an acute need to develop deposits currently considered sub-economic. The processing of such deposits may be more energy intensive due to the application of deep-level mining techniques. As a consequence, the energy requirements of the mining industries are expected to increase exponentially with an attendant increase in the generation of mine-related waste.

To sustain consistent competitive levels requires the development of processing technologies that:

- Require less energy,
- Consume less water,
- Require lower capital cost,
- Produce lower dust levels, gas emissions, and less toxic effluent, and
- Produce higher value-added graduation of final products.

2.1.5 Minerals Upgrading and Value Addition

<u>Beneficiation or mineral value addition is a deliberate government intervention to facilitate a shift from a resource-based to a knowledge-based economy</u>. This intervention is based on the acknowledgement of the country's rich endowment with mineral resources, which affords an opportunity to contribute to an accelerated economic growth. The beneficiations strategy is rooted in several policies including the MPRDA[4] and the BBSEE[5]. To further support the creation of an enabling environment for beneficiation in South Africa the Precious Metals Act[6] and the Diamonds Amendment Act[7] were introduced. This led to the establishment of the South African Diamond and Precious Metals Regulator (SADPMR) and the State Diamond Trader (SDT) respectively. In addition, the Department of Mineral Resources (DMR) has developed a beneficiation strategy to create a broader framework to promote increased local value addition consistent with other programmes of government such as the National Industrial Policy Framework, and the more recent Industrial Policy Action Plan (IPAP2).

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[4] Mineral and Petroleum Resources Development Act (No. 22 of 2002)

[5] Broad-Based Socio-Economic Empowerment charter for the South African mining and minerals industry

[6]The Precious Metals Act (No. 37 of 2005)

[7] The Diamonds Amendment Act (No. 29 of 2005)

2.1.6 Rehabilitation and Closure

Mining is a unique business operation in that it requires at its inception an approved plan incorporating the provisions for closure including the winding down of the business and the rehabilitation of the environment. Submission of a compliance plan with the National Environmental Management Act (107/1998) is required before mining can commence.

The initiation of mining activities also heralds the initiation of rehabilitation and closure activities. As mining (mineral extraction) activities advance, rehabilitation and maintenance of mined–out and stockpile areas proceeds. These activities include land, water and other impacted natural environment rehabilitation as stipulated in the approved resource management permits.

2.1.7 Post Closure Social and Labour Plans

The phenomenon of ghost towns arises as a result of the sharp rise in unemployment that follows mine closure and the exodus of related industries.

Post closure, social and labour plans are the most neglected areas in the mining industry value chain and South Africa is littered with 'Ghost Towns' (from Vryheid to some areas of Witbank and Middleburg) that bear terminal evidence of this phenomenon. The preferred approach is to use the existing mineral wealth, during exploitation, to diversify the local economy to become self-sustainable beyond the "Life of Mine" activities.

2.1.8 Environmental Management, Health and Safety

Mining impacts the environment in various ways through its negative effects on the air, land, water and people. These environmental impacts include erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In addition, the contamination resulting from leakage of chemicals may also affect the health of the local population. Mineral resources have been exploited in South Africa for nearly two centuries with limited environmental controls. Over the last two decades, stringent environmental regulations have been developed to prevent and reduce these negative impacts.

A summary of these environmental impacts are outlined below:

Both underground and open cast mining methods affect air quality
Particulate matter is released in surface mining when overburden is stripped from the site and stored or returned to the pit. Particulate matter is also generated when rock is broken or blasted during the mining process. When the soil is removed, vegetation is also removed, exposing the soil to the weather, causing particulates to become airborne through wind erosion and road traffic. In underground mining, extraction fans extract contaminated air from the mining face into the atmosphere and return clean air into the mining face. Particulate matter can be composed of toxic material such as arsenic, cadmium, and lead. In general, particulates affect human health adversely by contributing to illnesses relating to the respiratory tract, such as emphysema, but they can also be ingested or absorbed through the skin.

Surface subsidence and abandoned waste stockpiles.
Mining can cause physical disturbances to the landscape, creating eyesores such as waste-rock piles and open pits. Such disturbances may contribute to the decline of wildlife and plant species in an area. In addition, it *is possible that many of the pre-mining surface features cannot be replaced after mining ceases*. Mine subsidence (ground movements of the earth's

surface due to the collapse of overlying strata into voids created by underground mining) can cause damage to buildings and roads.

Water pollution problems caused by mining include acid mine drainage, metal contamination, and increased sediment levels in streams. Sources can include active or abandoned surface and underground mines, processing plants, waste-disposal areas, haulage roads, or tailings dams. *Water pollution affects fisheries, swimming, domestic water supply, irrigation, and other uses of streams*.

The environmental impact of mining activities has, hence, become one of the greatest areas of public interest in the mining industry. Concerns about acid mine drainage, heavy metals contamination, releases of tailings or other wastes into natural waters, and the general issue of mining industry's environmental footprint have led to a widespread negative public image for mining. The issue is exacerbated by the fact that problems at abandoned mine sites continue to occur. Innovative, economically viable and sustainable technical solutions are needed to address these persistent environmental challenges.

2.1.9 Technology Lateral Migration

Resource-based industries, such as mining, are a major source of wealth, employment, skills upgrading and export earnings. A resource base also provides a mechanism for successful diversification of the economy through industrialisation. Internationally, there are numerous examples of countries using their natural resources to secure sustainable industrial development.

The development potential of natural resources can be exploited in four main ways:-
- Beneficiation
- Downstream processing
- The development of internationally competitive input industries supplying the natural resources sector.
- The diversification of upstream or side stream industries into other unrelated sectors, also described as lateral migration

In South Africa, substantial innovation and scientific know-how has been generated for the purpose of dealing with specific challenges in the mining industry. There are global and South African examples of resource-based companies that have enabled the migration of technologies from resource-linked applications to those in higher growth, globally traded sectors. This offers an important opportunity for resource-based economies seeking to shift to higher value-added production.

2.1.10 Input Sectors

Using its mining activities as a base, South Africa has nurtured strongly competitive sectors providing sophisticated inputs and services to the global mining industry. Some South African companies are at the centre of global mining operations, services and technology. South African companies have become globally prominent in three areas, namely:

- technology providers to the global mining industry;
- providers of knowledge-based mining services; and
- specialist mining contractors.

The country has produced world-leading companies in mining explosives, drilling equipment and abrasives, metallurgical processes and plants, and delivering knowledge-based services to mines everywhere. The mining input sector was once one of the few fast-moving technology spheres and a significant number of South African companies are at the frontier of innovation. Selected examples of these companies are:-

- AECI and Sasol are leading suppliers of mining explosives,
- Boart Longyear is a world leader in drilling and abrasives,
- SRK and Bateman are among the leading consulting mining engineering companies in the world.
- LTA plays a major role in specialist contract mining in Africa.

To contextualise the opportunities presented by the inputs sectors it is necessary to consider that the global mining industry is more than four times the size of South Africa's economy.

3.0 Industry Profile and Performance

Since the late 19th century, South Africa's economy has been based on the production and export of minerals, which, in turn, have contributed significantly to the country's industrial development.

Research into the multiplier and induced effects of the mining sector indicate the following make-up of its GDP contribution:-

ITEM	CONTRIBUTION (%)
Direct GDP contribution	**8.6**
Backward linkages	2,3
Downstream linkages	2,2
Induced effects	6,0
	19.1

Table 1: 2010 GDP Make-Up[8]

It is thus acknowledged that South Africa's future economic growth will continue to be closely linked to the mining industry.

The in-situ value of 18 minerals investigated by EcoPartners translated to US$4.71 trillion including coal. According to a study by U.S. investment bank Citigroup, South Africa is the world's richest country in terms of its mineral reserves with the extent of its non-energy mineral wealth estimated at $2.5 trillion (R19.2 trillion). Russia and Australia are the next wealthiest mining jurisdictions with non-energy mineral wealth estimated at $1.6 trillion each.

The country is also one of the world's most important mining countries in terms of the variety and quantity of minerals produced. It has the world's largest reserves and production of PGM, chrome, gold, vanadium and manganese as depicted in the diagrams below. Some of these minerals are earmarked for beneficiation in the country's national beneficiation strategy document.

The absence of rare earths[9] being mentioned in the draft strategy document was pointed out. Since one of the main uses for rare earths is in green energy technology, it has been classified under energy minerals in Table. 2.

[8] South African Chamber of Mines publication: Facts & Figures 2010

[9] Rare Earth Elements (REE) or Rare Earth Metals (REM) is a collection of chemical elements that tend to occur in same deposit and exhibit similar chemical properties.

Precious Metals and Minerals	Energy Minerals	Ferrous Minerals	Base Metals	Industrial Minerals
Diamonds Gold Palladium Platinum Rhodium Silver	Coal Uranium Thorium Rare Earths	Chrome Iron Manganese Silicon Vanadium	Aluminium Antimony Cobalt Copper Lead Magnesium Nickel Titanium Zinc Zirconium	Aggregates & Sand Alumino-silicates Dimension stone Fluorspar Limestone Phosphate Rock Vermiculite

Table 2: Classification of key mineral sectors in South Africa

Eighty one percent of South African mineral commodity sales consist of gold, the PGMs, coal and iron.

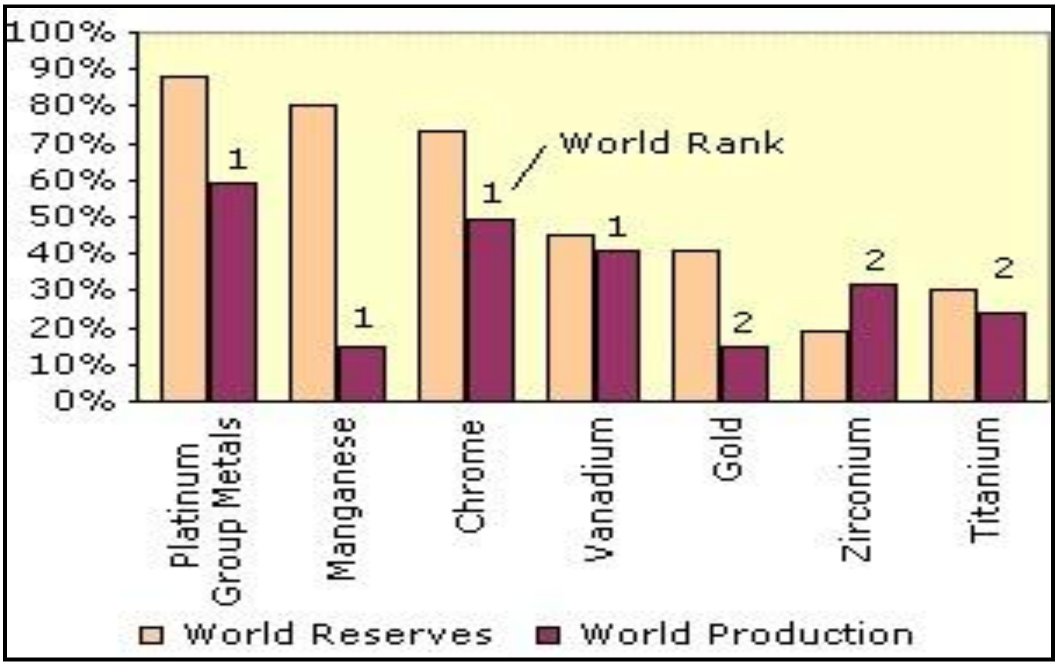

Figure 2: Summary of South Africa's top ranking minerals, 2007.
(Data source: Department of Minerals and Energy, 2009)

South Africa has since dropped to number 3 on the gold production rankings after China and Australia.

The South Africa Mining Sector has grown by only 0.5% (in real mining GDP), in dollar terms, between 2001 and 2008 (see table below) compared with an average 5% growth rate for the mining GDPs of the top 20 mining economies.

COUNTRY	MINING REAL GROWTH (%)
South Africa	0.5
China	19
Chile	12
Russia	10
Indonesia	8
Australia	7
Venezuela	4

Table 3: Industrial Development Corporation of South Africa: Sectoral Trends; 1st Quarter 2012

Mineral Production Growth Rates of Selected Commodities (1990 – 2009)

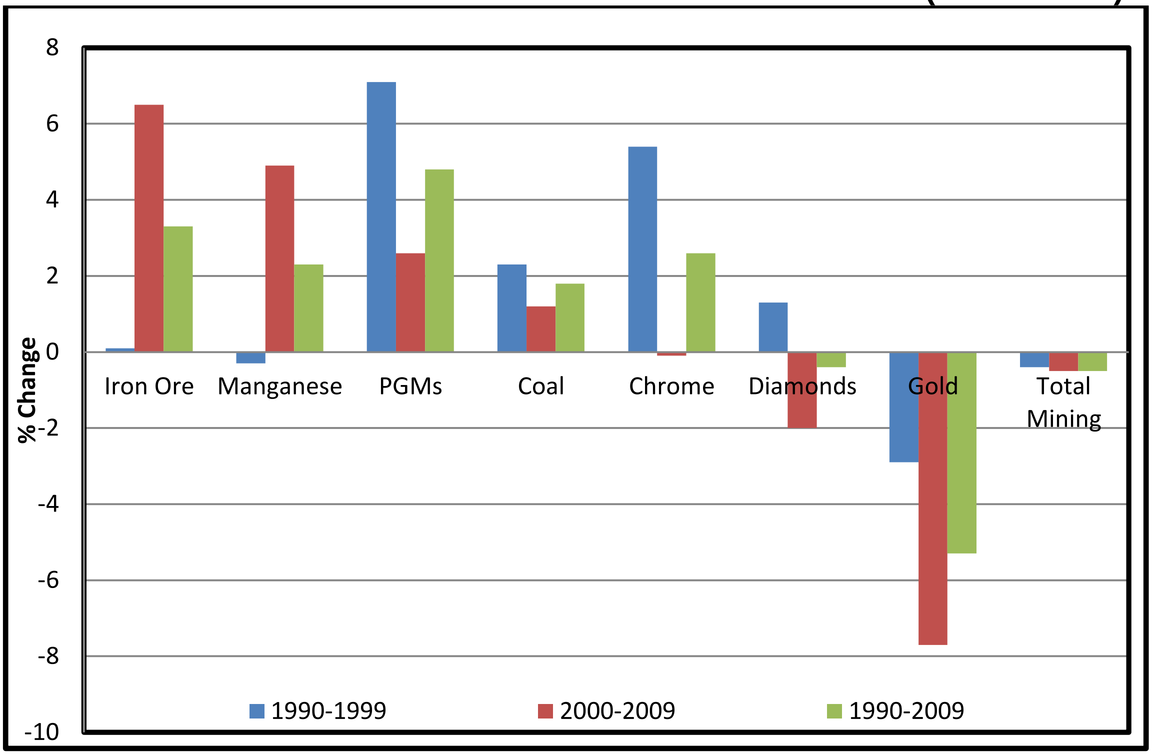

Figure 3: Chamber of Mines of South Africa 2010 Report (Page 26)

The selected, and plotted, sub-period between 1990 and 2009 are designed to highlight and contrast the magnitude of the changes in production within the selected mineral types. In the two decades up to 2009, total mining production fell by 0.4% per annum, with a more pronounced decline of 1% in the second decade, driven:-

- by the 5.3% per annum decline in gold production, and the
- 0.4% per annum decline in diamond production.

Although minerals such as PGMs increased by 4.8%, iron ore by 3.3% and manganese by 2.3% in the same period, the significance of the declining minerals in the economy slanted the production performance to negative.

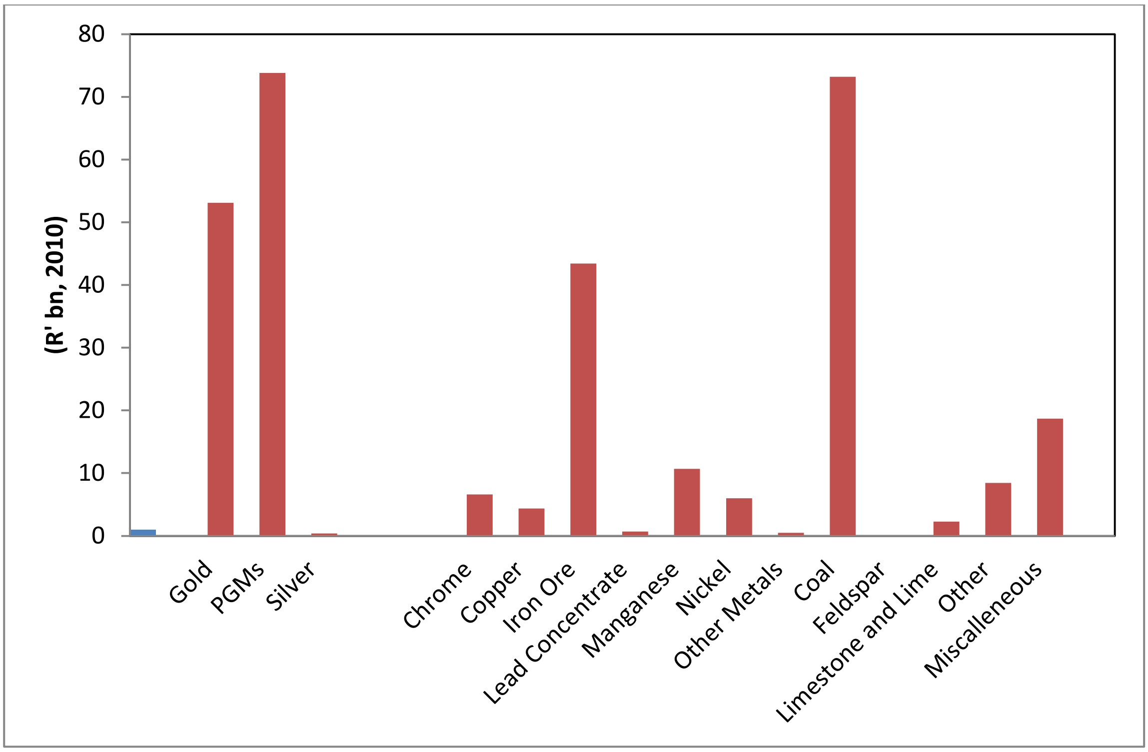

Figure 4: Chamber of Mines of South Africa (2011), Mineral sales by Commodity

The value of South Africa's mineral sales in 2010 rose by 24.9% to R 302.2 billion driven by the rebound in commodity prices coupled with a 13.2% appreciation in the R/US$ exchange rate. This figure places the sales value, in nominal terms, at 2008 sales levels. Only four minerals, being, the PGMs, Coal, Gold and Iron Ore accounted for 81% of the total South African sales value.

4.0 Sector System of Innovation

The diagram below depicts a simplified conceptual view of the sectorial system of innovation.

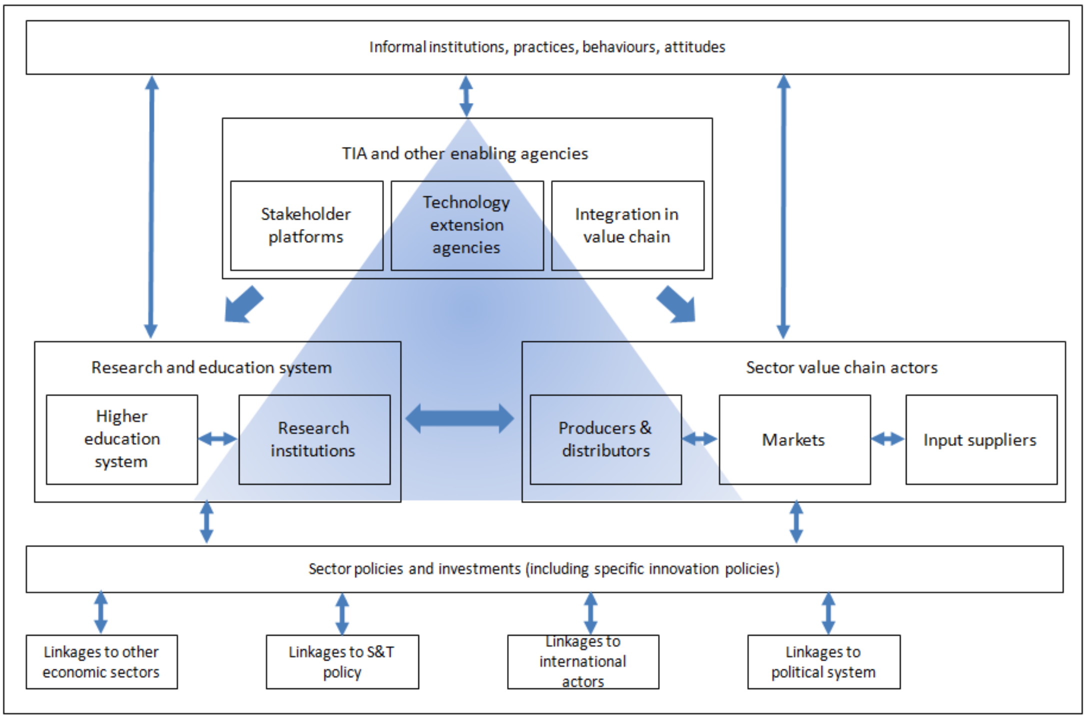

Figure 5: Schematic representation of sectorial system of innovation based on TIA's interpretation

This diagram provides a useful approach where this system can be defined as "a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with institutions and policies that affect their behaviour and performance".

This approach allows for highlighting ways in which heterogeneous actors interact in the generation, exchange and use of information and knowledge; how individuals and organisations learn and change; and how social and economic institutions condition these interactions and processes. Using this approach, it is possible to develop insights into ways of increasing both the efficiency and effectiveness of innovation processes by identifying and exploiting comparative advantages of different actors and organisations; reducing transactional costs in the exchange of information and technology; and achieving outcomes of scale and scope; exploiting complementarities, and realising synergies in innovation. In the South African mining industry, the actors and activities from the value chain perspective are made up as follows:

4.1 Role Players in the Mining and Minerals Value Chain

Workshops and discussions were held with sector role players (MIGDETT[10], Beneficiation Conference[11], SARIMA[12] and SACMA[13]) where inputs were collated into table 4 to reflect the different sector role players in the sector system of innovation.

	Exploration	Mining	Mineral processing	Mineral and metal beneficiation
Research and education system actors	Council for Geoscience, Universities	Council for Scientific and Industrial Research (CSIR), Mine Health and Safety Council (MHSC), Universities	Mintek, Universities	Mintek, CSIR, Nuclear Energy Corporation of South Africa (Necsa) and Universities
Sector value chain actors	Consulting companies, geophysical service companies and mining companies	Mining consulting companies, equipment manufacturers, mining companies	Process consulting firms, equipment manufacturers, chemicals suppliers	Mintek, CSIR, Necsa and Universities
Enabling agencies	National Research Foundation (NRF), TIA, Industrial Development Corporation (IDC), Provincial economic developing agencies, Department of Mineral Resources (DMR), Department of Science and Technology (DST), Department of Water and Environmental Affairs (DWEA), Dept. of Land Affairs, **the Department of Trade and Industry (dti) and** Non-governmental Organisations (NGOs)			
Sector R&D Funding Agencies	*Safety in Mines Research Advisory Committee (SIMRAC), Coaltech Research Association, South African Minerals to Metals Research Institute (SAMMRI)*			
Key activities	Research and development, technology development and exploration services	Mine health and safety, energy and water efficiency, mine design, technology development, environment and mine of the future	R&D in process technology, process efficiency, water and energy efficiency, health and safety, and environment protection.	Advanced Manufacturing Technology Strategy (AMTS), Advanced metals initiative, project AuTek, PGM beneficiation, Minerals beneficiation strategy

Table 4: Role players in the Mining and Minerals Sector System of Innovation

[10] Mining Industry Growth, Development and Employment Task Team (2011)
[11] Minerals Beneficiation Conference (15 to 18 May 2012)
[12] South African Research and Innovation Managers Association (26 March 2012)
[13] South African Colliery Managers Association (5 April 2012)

5.0 Pestle Factors (Macro Environmental Factors)

This section summarises the PESTLE (Political, Economic, Social, Technological, Legal and Environmental) factors that impact on the mining and minerals sector.

Political	Economic	Social	Technological	Legal	Environmental
Acts MPRDA BBSEE Research & Technology competitive edge Partnerships with R&D institutions Integrated sustainable development approach Comparative advantage to competitive advantage	Commodity needs in fast growing economies Uncompetitive labour productivity Exchange rate MIGDETT Infrastructure	Skills shortages High average age of mining professionals Literacy HIV/AIDS Respiratory diseases Social licence to mine	Innovation constraints Impact all areas of mining value chain Productivity Safety Emerging technologies R&D contracted to overseas agencies	Resource taxes and royalties Licensing New Royalty Bill Safety performance AEMFC	Industrial water usage Acid Mine Drainage Air pollution Noise pollution Land rehabilitation

Table 5: PESTLE Factors impacting the mining and minerals sector

5.1 Political factors

At a policy level, the mining and minerals industry sector is underpinned by a number of legislative provisions. The major piece of legislation is the Minerals and Petroleum Resources Development Act (Act No. 28 of 2002) (MPRDA), which provides for equitable access to and sustainable development of the nation's mineral and petroleum resources. The MPRDA transferred minerals ownership to the nation, with the State as custodian. A major implication of the Act was that mineral rights previously in private hands became subject to "use it or lose it" provisions, leading to greatly increased exploration activity in South Africa. Before the Act, major mining companies were content to own mineral rights with the intent of exploiting them in the future. Now, operators licensed to mine particular mineral rights are obliged to exploit, or lose their licenses.

To give effect to the legislative provisions, mining stakeholders negotiated a charter and declaration in 2003 that was updated in September 2010 (Amendment of the Broad-Based Socio-Economic Empowerment Charter for the South African Mining and Minerals Industry). The charter and declaration, in the context of this plan, advocate for:

- Parties to work towards attainment of a research driven and technology based competitive edge, by amongst others
  - Supporting a research and development culture in the mining industry; and
  - Strengthening the partnerships with research institutions both locally and internationally.
- Balancing the economy with social needs, by amongst others
  - Ensure sustainability of mine closure and mining environmental plans.
  - Adopt an 'integrated sustainable development approach' through pooling of resources.
- Translating comparative advantage in mineral resources endowment into competitive advantage to fuel further industrialisation and value addition, by amongst others supporting local beneficiation and ensuring greater local processing of SA's abundant natural resources.

Other legislation that regulates the sector are the Mine Health and Safety Act, 1996 (Act No. 29 of 1996), the Mine Health and Safety Amendment Act (Act No. 74 of 2008), the Diamonds

Act, 1986 (Act No 56 of 1986), the Diamond Amendment Act, 2005 (Act No 29 of 2005), and the Precious Metal Act, 2005 (Act No 37 of 2005).

A confluence of the said legislative framework and attractive commodity prices saw a rise in the number of new entrants who have applied for prospecting and mining licences. Furthermore, the new legislative regime tries to mitigate concerns that industry will not meet its BEE targets by 2014 as well as the completion of the conversion to new order mining rights.

Other political issues include continued debate on resource nationalisation as well as a slow and somewhat uncertain licensing environment which may undermine investor confidence.

5.2 Economic factors

The global economic factors place increased pressure on the mining industry to be more responsive in order to remain competitive and productive. Despite the high demand for commodities in the Chinese and other economies, the sector has performed worse than the rest of the economy (See Section 3) and its peers globally. This performance was influenced by factors such as energy supply constraints, uncertainty in the legislative framework, uncompetitive labour productivity and currency exchange rate. This resulted in cost cutting measures that negatively affected expansion projects, reduced job retentions, increased mine closures and negatively impacted on the environment and surrounding communities.

In December 2008, the mining sector stakeholders from government, organised labour and employers responded to the economic crisis by establishing the Mining Industry Growth, Development and Employment Task Team (MIGDETT). This task team is focused on ways to manage the crisis in the short term and repositioning the sector for the next commodity up-swing. ***MIGDETT is currently developing a strategy for a sustainable growth and meaningful transformation of the South Africa's mining sector***.

5.3 Social factors

The mining industry experiences skills shortages in areas such as professionals, technicians and trades workers, directors and corporate managers, machine operators and drivers. In addition, a recent study found that the average age of mining professionals in South Africa is between 50 and 55 years.

The sector has among the highest number of illiterate employees, high levels of HIV/AIDS infections and a high incident of respiratory health conditions.

There is also increased emphasis on social licence to mine, which includes commitment to the development and implementation of social and labour plan.

5.4 Technological factors

As stated in the National Beneficiation Strategy, limited innovation is a constraint in the development of the sector. New technology developments will have an impact on all areas of the mining value-chain. These include robotics and mechatronics and diagnostic sensors, which will impact on increased productivity and safety in mineral exploration, mining and mineral processing.

In mineral exploration, while remote sensing cannot replace conventional geotechnical methods of investigation, emerging technologies such as hyper-spectral imaging and interferometric synthetic aperture radar should not be ignored. These technologies are already widely used to monitor ground subsidence, landslides, volcanoes, and active faults.

With the advances in computer technology the integration of remote sensing tools into mining applications will also increase.

5.5 Legal factors

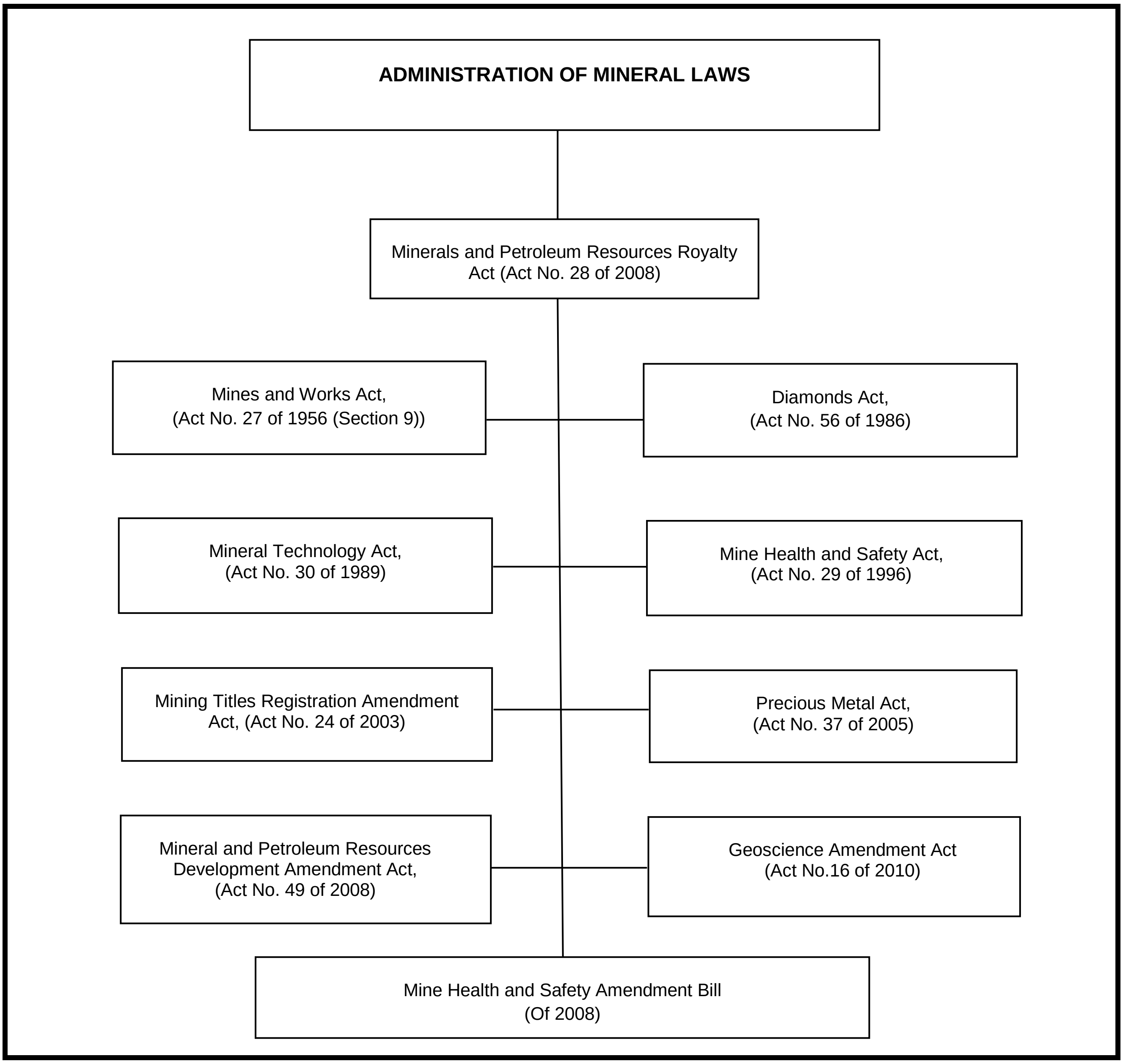

Figure 6: Schematic representation of the administration of the Mineral Laws of South Africa;
Source: South African Minerals Industry (SAMI) 2009/2010; dmr: Directorate Mineral Economics; p4

Throughout 2010 and 2011, numerous countries have taken steps to protect their sovereign assets by imposing new resource taxes and royalties, forming national resource entities and tightening their licensing practices. In South Africa, the Mineral and Petroleum Resources Royalty Act (Act No. 28 of 2008) was promulgated on the 24th November 2008. The Minerals and Petroleum Resources Development Act (Act No. 28 of 2002), was promulgated to provide for equitable access to and sustainable development of the nation's mineral and petroleum resources. Pressure on improvement of safety performance remains and is driven by milestones set by the industry in 2003. The Mine Health and Safety Amendment Act was promulgated in 2008 and is again currently under review. The amended act was introduced to among others, strengthen enforcement provisions; simplify the administrative system for the issuing of fines; and reinforce offences and penalties.

The African Exploration Mining and Finance Corporation (AEMFC), South Africa's own national resource mining entity, was re-launched in 2007 (after being dormant since its establishment in 1944). It has been granted prospecting and mining rights, in competition with other mining companies. In February 2011, the AEMFC launched a coal mining project in Mpumalanga that plans to produce 1.68 million tons per annum of coal.

5.6 Environmental

The extraction and processing of minerals is closely linked with other natural resources like land, water, air and vegetation. Hence, the management of these natural resources and its optimal and economic exploitation are matters of national importance.

It is expected that the Department of Water Affairs will increase visibility and sanctions on industrial water usage. The mining sector has continually been challenged by the management of *acid mine drainage* (AMD). Disputes between government and mining companies over the cost of cleaning up the toxic water caused by mining have led to the rapid rise in the water level following the partial closure of a water treatment plant outside Randfontein. Other environmental factors include air pollution, noise pollution and land rehabilitation.

6.0 SWOT Analysis

	Internal	
	Strengths	**Weaknesses**
	• Resource abundance • Foreign direct investment • High level expertise in limited areas • Primary processing facilities • Global leader in some technologies	• State of research institutions • Limited R&D funding • Skills shortage • Low minerals value addition • Low international R&D collaboration • Slow sector transformation • Few new entrants • Adoption of innovation
External	**Opportunities**	**Threats**
	• Platinum beneficiation • Supply side/upstream industry expansion • Health and safety and hazards management environment development • Local manufacturing • Downstream beneficiation • Employment creation • Wealth creation • Development of sustainable livelihoods • Lateral migration of technology	• Declining R&D funding • Electricity supply shortages • Skills affected productivity and safety • Non-generation of new skills • Lack of local R&D collaboration by industry • Transport infrastructure deficiencies • Imports of products and services

FIGURE 7: THE SOUTH AFRICAN MINERALS SECTOR SWOT ANALYSIS

6.1 Strengths

- South Africa has abundant natural resources and a substantial percentage of the world's reserves in platinum group metals, gold, ferrochrome and manganese.
- There are pockets of good research programs in some of the local institutions.
- The industry attracts large amounts of foreign direct investment and generates over 50% of foreign exchange for the country through exports.
- As a major mining country, South Africa's strengths include a high level of technical and production expertise as well as comprehensive research and development activities.
- The country has world-scale primary processing facilities for carbon steel, stainless steel and aluminium, gold and platinum.
- It is also a world leader on new technologies, such as a ground breaking process that converts low-grade superfine iron ore into high-quality iron units.

6.2 Weaknesses

- A shortage of highly skilled and trained workers in high-technology areas and industry.
- State of research institutions.
- The industry exports more minerals in primary, un-beneficiated form with minimal value addition.
- Insignificant mining and minerals R&D collaboration with international counterparts.
- Slow pace in transforming the sector and entry of new players.

6.3 Opportunities

- The development and uses of beneficiated platinum for fuel cells, catalysts and high-strength alloys.
- The industry already has well-established companies in both mining and mining equipment that the government could leverage to develop local manufacturing capabilities and technology adoption.
- Increased focus on developing downstream beneficiation activities will create employment, increased revenue generation for the local mining industry and balance of payment in the broader economy.
- Technologies developed to support the mining sector can be used to create new economic sectors through lateral migration.

6.4 Threats

- Decreased funding from mining companies and government for R&D in the mining industry.
- Government investment in electricity generation capacity not staying abreast of supply demands.
- Decreased productivity and safety standards as inexperienced staff fill the skills gaps.
- The need for new and deeper skills and capacity across the industry is universally recognised.
- The lack of local R&D collaboration amongst industry role players could lead to high tariff duties on imported capital equipment, which decreases the ability of the industry to purchase large amounts of required machinery and equipment, and improve productivity.
- Transport and logistics are challenging with insufficient road and inefficient and insufficient rail infrastructure to handle current and increased demand.

7.0 VISION, MISSION AND BUSINESS UNIT OBJECTIVES

7.1 Vision

To enable a knowledge intensive and competitive mining and minerals sector through supporting innovation and commercialisation.

7.2 Mission

To develop and support innovative projects through to market readiness that will minimise the innovation chasm through directed focus, appropriate funding instruments and leveraged partnerships.

7.3 Business Unit Objectives

The Business Unit Objectives for the mining sector that support the above Vision and Mission are:

- Efficient, Safe and Competitive Production: Use advanced technologies to improve process efficiencies from exploration to final product and reduce worker exposure to hazards as well as maintain a competitive mining sector.

- Environmental and Health Management: Support the development of technologies to minimise the impact from mining activities on its workforce, the environment and the community.

- Minerals Upgrading and Value addition: Support the upgrading and value addition of South Africa's minerals, also by encouraging local manufacturing and production.

- Lateral migration: Exploit the knowledge and capacity in the mining sector to create new high-value economic sectors.

- Innovation culture through skills development: To facilitate the development of innovation skills to support technology innovation and commercialisation.

8.0 FOCUS AREAS TO SUPPORT THE BUSINESS UNIT OBJECTIVES

8.1 Exploration

Activities	Needs
• Basin modelling • Structural geology • Geochronology • Target generation • Mapping • Geophysics • Geochemical analysis • Drilling • Aerial photography • Satellite imagery • Geophysical surveys	• Applied geosciences as knowledge based industry of geology • Innovative technologies in geology • R&D to improve ability of geophysical tools

Modern mineral exploration is largely technology driven. The use of new technologies and methods could increase the effectiveness and productivity of mineral exploration. The most promising of these are the combination of space-borne remote sensing with traditional techniques, and new developments in deep electromagnetic and gravity imaging. The most advanced to date is the use of hyper-spectral systems and interferometric synthetic aperture radar systems. More government support is necessary to ensure that this technology is developed to a stage that warrants commercialisation.

In the field of geological sciences, increasing support of basic science would provide a significant increase in the effectiveness of mineral exploration. Fundamental knowledge, in for example detailed four-dimensional geological frameworks of ore systems, would support mineral exploration and development, as well as mining and minerals processing, thus increasing the investment-potential of the sector.

The outcome of exploration feeds into techno-economic feasibility studies and investment evaluation. A decision gate is then reached whether to proceed to mine design and development.

8.2 Mine Design and Development

Activities	Needs
• Infrastructure development plans • Process and technology selection and decision making	• Impact assessment • Technology assessment

This involves the interpretation of drilling data that informs the most optimal and economic mine design. The interpretation identifies the location of the initiation of mining activities, the mine layout and the limits of the deposit.

8.3 Mining

Activities	Needs
• Extraction ore from earth • Extraction of minerals from ore body • Surface mining (open cast) • Underground mining • Monitoring • Information management per mining stage	• Deep mining • Geomechanical processes • Geothermal management • Mechanisation • Remote mining • Safety • Environmentally friendly techniques and processes • Rehabilitation • Improvement of mining processes/logistics/assets • Management and information systems

The search for new and innovative mining technologies that would increase productivity, improve health and safety and maintain competitiveness has been relentless since the early nineties. The recent growing awareness of the adverse environmental and ecological impacts of mining has provided an additional driver.

Increasing Depths of Mining: As mining progresses to greater depths, increases in rock stress require innovative designs to ensure the short-term and long-term stability of the mine structure.

Continuous Mining: Truly continuous mining will require an accelerated search for innovative *fragmentation* and material handling systems.

Real-Time Information Systems: Techniques for sensing, analysis, and communication and information management have become increasingly important. Each mining environment presents unique challenges to the design and operation of equipment. Increasing the productive operating time of equipment and mining systems will require modern monitoring technologies.

The entire mining process would benefit from technology advancement in many sectors. However, focus should be primarily in four key areas:-

(1) Rock fragmentation with the goal of achieving continuous mining and conserving overall energy consumption;
(2) Sensors and sensor systems for mechanical, chemical, and hydrological applications;
(3) Data processing and visualisation methods that produce real-time feedback; and
(4) Automation and control systems.

The focus should be on developing technologies that will make South African mining more competitive by building new generation mines ("mine of the future").

8.4 Minerals Processing

Activities	Needs
• Extraction • Preparation • Purification • Physical extraction • Chemical extraction • Pyro-metallurgical extraction • Hydro-metallurgical extraction • Magnetic extraction • Biological extraction • Waste handling	• Low energy processes • Water saving processes • Low capital injection • Low dust levels • Low gas emissions • Low toxic effluent • Higher value added final products • Improved services and products from input industry • Improved process control instrumentation

Specific technology developments in minerals processing has cross-sector benefits. These development areas include energy efficiency of unit processes such as comminution through *selective liberation* and optimal mineral sizing.

Processes technology needs to focus mainly on:-

- separation of water in disposable solids,
- selective flocculation applications.
- developing efficient ore-sorting methods

Other technological development areas should be focused on innovative reactor designs and materials, sensors, modelling and simulation and processing.

8.5 Minerals Upgrading and Value Addition

The following are typical activities and needs for this phase of the value chain:

Activities	Needs
• Refining • Pelletising • Conversion • Mill product • Casting • Alloying • Heat and surface treatment • Finishing • Materials and process design	• Process quality control • Infrastructure optimisation through innovation • Reaching economy of scale

Current beneficiation efforts include the Titanium Industry Development programme and the Advanced Metals Initiative. To give impetus to these efforts, the Department of Minerals and Energy developed the national minerals beneficiation strategy. The Minerals Beneficiation Strategy identified the following cross cutting constraints and initiatives to support beneficiation developments: limited access to raw materials for local beneficiation; shortage of Critical Infrastructure; limited exposure to R&D; inadequate skills; and Access to international markets. It must be recognised that for beneficiation to be successful it must be market-driven and better integrated by developing up- and down-stream aspects to support the sustainability of the markets. Some key minerals that present opportunities for beneficiation for South Africa, some of which are also identified in the National beneficiation strategy, are summarised in the table 7.

Supporting legislation, long term strategies and initiatives for beneficiation include the following:

- National Beneficiation Strategy
- Mineral and Petroleum Resources Development Act (MPRDA)
- Broad Based Socio-Economic Empowerment (BBSEE)
- Precious Metals Act No. 37 of 2005
- Diamonds Amendment Act No. 29 of 2005
- South African Diamond and Precious Metals Regulator
- State Diamond Trader
- National Industrial Policy Framework
- Industrial Policy Action Plan

The following supporting programmes are also available to support the beneficiation strategy:

- The DST Technology Assistance Programme to the National Foundry Technology Network (NFTN)
- The Nuclear Energy Act (Act No 46 of 1999)
- National Industry Participation Programme (NIPP) of the Department of Trade and Industry **(the dti)**
- Competitive Supplier Development Programme (CSDP) for State-owned Enterprises (SoEs) to develop the local supply industry
- Customised Sector Programmes of **the dti**
- Technology and Human Resources for Industry Programme (THRIP) of **the dti** managed by the National Research Foundation (NRF)
- The Support Programme for Innovation in Industry (SPII)

The key strength of the mining industry lies in South Africa's access to natural resources, which provides a base for mineral beneficiation. This in turn provides opportunities for local companies and research institutions to develop advanced products and technologies. Minerals upgrading and value addition activities in the country include:

- over 30% of the country's liquid fuels are made locally from mined coal through the Coal to Liquids process (Sasol);
- 20% of the world's platinum catalytic convertors are made in South Africa; and
- 95% of electricity is generated in power plants that use locally mined coal.

8.6 Rehabilitation and Closure

Activities	Needs

• Winding down mines
• Rehabilitation
  • Land
  • Water
  • Biodiversity
	• Reprocessing
	• Landscape design
	• Monitoring of physical stability and mine water
	• Ecosystem design

The activities and needs arising from the discussions during the workshop are listed above. The rehabilitation of mined out areas, shafts, open pits and impacted environment remains one of the prominent on-going challenges of mining jurisdictions.

8.7 Post-closure social and labour plans

Activities	Needs
• Redeployment of labour • Exodus of supporting industries	• Diversify the local economy • Self-sustainable beyond Life-of-Mine

Mining is a finite economic activity with a defined economic lifespan within a defined resource. The emergence of the phenomenon of “Ghost Towns”, post closure, necessitates the need for diversifying economic activities of these mining areas during the economic lifespan of the mining activities.

8.8 Input industry

Activities	Needs

• Products
• Services
• Globalisation
  ➢ Technology providers
  ➢ Knowledge based mining services
  ➢ Specialist mining contractors
	• Mining explosives
	• Drilling equipment
	• Abrasives
	• Metallurgical processes and plants
	• Delivery of knowledge based services
	• Import substitution of processing chemicals
	• Safeguarding from strategic risks such as in PGM industry of the future (e.g. catalysts)
	• Supply of improved control instrumentation
	• Support systems
	• Materials handling

The support for the input industries is also paramount to a sustainable and competitive mining sector. There are support industries that have grown to be global players in their respective areas of expertise on the back of the South African mining sector.

8.9 Environmental Management, Health and Safety

Activities	Needs
• Air quality • Surface subsidence and abandoned waste stockpiles • Water pollution (acid mine drainage, heavy metal contamination, increased sedimentation)	• Air extraction, filtering and recirculation • Land stabilisation and rehabilitation • Environmental impact and purification • Transport systems • Roof stability and sidewall support • Disaster prediction and management solutions

All mining sectors would benefit from new technologies that improve sustainability of operations by minimising adverse environmental impacts. The on-going and long term negative impacts on water quality related to current operations and decommissioned mines are often the most challenging and costly to address for all types of mining.

New technologies for managing environmental concerns, such as innovative, cost-effective solutions to managing slime dams could also improve productivity. In addition, focus should be increased on the commercialisation of technologies that improve health and safety such as monitoring devices, sensors to detect hazards and better structural support.

8.10 Technology Lateral Migration

Activities	Needs
• Diversification through industrialisation • Sectorial linkages	• Beneficiation • Downstream processing • Input industry development • Diversification of upstream or side-stream industries

The support for further development and commercialisation of technologies, developed in support of the mining sector or other sectors, to migrate into the mining sector (or vice versa) where such opportunities present is also considered within the ambit of this sector strategy.

9.0 Building an Innovation Culture through Skills Development

A sustainable innovation culture requires the following key elements:-

- Executive leadership - In order to take root, the innovation program requires constant input and guidance from executive leadership.

- Skills development - innovation is a process that can be learned and mastered. To support innovation in mining the training and resource development programs need to build innovation process skills as a core competency in the teams. It should be fairly obvious that the task of identifying a new application for a core technology is quite different from the task of improving production efficiency. Both tasks may lead to innovative solutions, but each will follow a very different path of discovery.

Taking the above into consideration, a tiered innovation skills program is then recommended. At the first level of skills development, knowledge workers should be trained in the basics of innovation methodology. They should be given the tools they need to address medium-complexity problems that are common to their job function and low-complexity problems. This will allow them to experience early success and practice their innovation thinking on a daily basis. Additionally, the newly trained innovation worker should be shown how to identify problems beyond their current grasp and how to seek help elsewhere in the organization to tackle these issues.

As innovation workers gain skill, advanced training should teach the methods of solving problems into the high-complexity range and specific methods related to common cross-functional problem sets. Finally, innovation workers that show the desire to master the full gamut of innovation methods can be trained in the low-frequency innovation methods as well as facilitation skills.

Following such a template helps the organization build pervasive basic innovation skills and also a core team of high-skill, innovation resources that can be leveraged. The cultivation of innovation skill in the enterprise is important for developing a sustainable innovation culture.

Innovation infrastructure - Another interesting aspect of the innovation process is that it can be influenced environmentally. The mastery and correct application of the process can be greatly aided by the use of an innovation platform that reinforces the application of innovation best practices. Great innovations happen when the insightful domain expert meets with the confluence of relevant knowledge and is thus able to synthesize something new. With this realization, it should be apparent that the proper use of information technology to help place the innovation worker at the apex of relevant and actionable knowledge when and how they need it is a powerful way to drive the success of innovation efforts.

The TIA support programs will endeavour to embed a culture of human capacity development in all its funding initiatives.

10.0 Implementation Monitoring and Evaluation

The monitoring and evaluation of implementing the goals as outlined in this strategy document are shown in the table below.

Revised metrics: Base Lines to be established for measurement and reporting

Goal	Metric
Efficient, Safe and Competitive Production: Use advanced technologies to improve process efficiencies from exploration to final product and reduce worker exposure to hazards as well as maintain a competitive mining sector.	• Percentage increase in uptake of locally developed and/or commercialised technologies to improve mineral reserve knowledge, sector safety and productivity for global competitiveness. • Percentage investment in mining and minerals related innovation programmes implemented with a market uptake • Number of mining related technology stations established
Environmental and Health Management: Support the development of technologies to minimise the impact from mining activities on its workforce, the environment and the community.	• Percentage increase in uptake of locally developed and/or commercialised technologies to reduce negative mining environmental footprint
Minerals upgrading and value addition: Support the upgrading and value addition of South Africa's minerals, also by encouraging local manufacturing and production.	• Percentage increase in uptake of locally developed and/or commercialised technologies that make minerals upgrading and value addition economical and globally competitive
Lateral migration: Exploit the knowledge and capacity in the mining sector to create new high-value economic sectors.	• Percentage increase in uptake of locally developed and/or commercialised technologies successfully deployed across sectors
Establishment of an innovation culture: Build an innovation culture through leadership, skills and support infrastructure.	• Increase in percentage of projects succeeding in commercial application as a result of an enhanced innovation content

Table 6: *Achieving strategic goals through measurement (Aligned to Operational Plans)*

Table 7: Key Minerals for Beneficiation

Mineral	SA Semi-processed	SA Downstream production	Opportunity	Timeframes Years
Diamond	4% polished diamonds	0.02% retail diamonds	SA has tended to focus on cutting large stones. To remain competitive, capacity for cutting small stones needs to be developed. The major competition in this area is India and China.	Short-term 5
PGM's	71% of refined metal	28% auto catalysts, 7% jewellery, 0.3% investment bars and the rest at 0.1%.	SA has a reasonable market share in auto catalysts manufacturing supported by the Motor Industry Development Program. Future opportunities exist in jewellery manufacture, and more significantly in electronics and high-technology metals.	Medium-term 10
Uranium	1.3% yellow cake	0% fuel pellets	Current efforts indicate renewed interest in increasing uranium production. As demand for fuel pellets continues to rise sharply, opportunities exist for SA to mine and beneficiate uranium to produce fuel pellets.	Long-term 15
Iron	0.7% pig iron, 3% pig iron exports and 2.9% directly reduced iron.	A variety of products are produced at varying market share.	SA exports approximately 62% of iron ore. Opportunities exists for SA to beneficiate most of its iron ore to support local manufacturing and supply for construction and mining.	Short-term 5
Manganese	43% manganese metal	20% high carbon ferromanganese, 20% refined ferromanganese, 48% silico-manganese and 20% carbon steel	Manganese beneficiation is linked to iron beneficiation as the metal is used extensively in steel production. Other non-steel markets that can be exploited include chemicals and storage batteries.	Short-term 5
Titanium	50% titanium slag	DST is funding research on Titanium powder production.	Opportunities exist in production of pigments, aerospace parts and medical implants. Some R&D has been initiated and focus should be on development to commercialisation.	Medium-term 10
Zirconium	32% concentrate	None	The largest market is ceramics but opportunities also exist in chemical products and nuclear industry.	Medium-term 10
Alumino-silicates	77% andalusite	None	Demand is driven by steel industry, however, there is potential to develop high-technology polymers.	Long-term 15
Fluorspar	0.1% concentrate	Small amount of hydrofluoric acid	Opportunities exist and increasing market share of hydrofluoric acid.	Short-term 5
Rare earth minerals			China currently accounts for 95% of rare earth minerals production and is currently imposing restrictions on exports. The minerals are vital in the manufacturing of hybrid cars; super alloys used in the defence industry, cell phones, large wind turbines, missiles and computer monitors. Recent reports identify South Africa and Canada as having strong potential for the supply of these minerals.	Medium-term 10

Table 8: Summary of Recommendations for Technology Development

	Exploration	Mining	Processing	Beneficiation
Short term (0-2 Years)	• Evaluate existing remote sensing technologies for use in exploration	• Improve surface-underground communication systems • Develop sensors for monitoring entire mining environment • Develop devices to monitor personal exposure to health hazards (noise & dust)	• Improve comminution technology • Develop improved technologies for physical separation and dewatering • Develop sensor for process stream and mine waste characterisation and control	• Develop technologies for value addition to minerals economically • Mine waste reclamation for economic use
Medium term (2-5 Years)	• Develop real-time mineral content sensors • Develop tools and techniques for exploration deep under cover	• Develop advanced simulation systems • Develop technologies for early warning systems for catastrophic failures	• Develop bio-extraction technologies • Develop tracers for mined product and early stage or in-situ separation • Develop new mine planning tools and technologies for improved utilisation of resources and minimum environmental impact	• Develop technological processes (hydro, bio, pyro- beneficiation) for treatment of complex waste • Titanium for pigments and advanced metals • Zirconium for chemical products and nuclear fuel
Long term (>5 Years)	• Improve accuracy of beneath the surface sensing of rocks, minerals and structures.	• Develop autonomous mining equipment • Develop robotic technologies for mining currently inaccessible deposits • Develop knowledge management techniques to improve mine management through real-time tools • Robotics for accidents site inspection and recovery	• Improve real-time analytical techniques for material analysis • Develop technologies for processing by-products	• Uranium/thorium for nuclear power generation • Rare earth minerals for electronics and advanced materials
	Mine of the future – minimum footprint linked to localised economic development through integrated sensors, robotics, and controls.			

Glossary of Terms

Abrasives – Any natural or artificial substance suitable for grinding, polishing, cutting, or scouring. Natural abrasives include diamond, emery, garnet, silica sand, diatomite, and pumice; manufactured abrasives include esp., silicon carbide, fused alumina, tungsten carbide and boron nitride.

Acid mine drainage (AMD) – It is the acidic run-off water from mine waste dumps and tailings dams containing sulphide minerals. This also refers to ground water pumped to surface from mines.

Alloy – A substance having metallic properties, and composed of two or more chemical elements, of which at least one is a metal.

Aluminium – A light, silvery-white, ductile metal with high electrical conductivity and good resistance to corrosion. Obtained from bauxite, it is the lightest of the metals in general use commercially and is the basis for light alloys used in the construction of modern aircraft and rockets; aluminium coatings are used for telescope mirrors, decorative paper, packages, and toys.

Alumino-silicates – Alumino-silicate minerals are minerals composed of aluminium, silicon, and oxygen. They are a major component of kaolin and other clay minerals.

Antimony – Metallic antimony is an extremely brittle metal with a flaky, crystalline texture. It is sometimes found native, but more frequently as the sulphide, stibnite (Sb_2S_3). It is used in semiconductors, batteries, antifriction alloys, type metal, small arms, tracer bullets, cable sheathing, flame proofing compounds, paints, ceramics, glass, and pottery. Antimony and many of its products are toxic.

Base Metals – Metals that oxidises when heated in air, as opposed to noble metals such as gold and platinum. Generally refers to the high-volume, low-value metals copper, lead, tin, and zinc.

Beneficiate – To improve the grade by removing associated impurities; to upgrade.

Beneficiation – The transformation of a mineral (or a combination of minerals) to a higher value product for the local or export market. This implies a further processing of ores beyond primary concentration to produce high value products.

Catalyst – A substance capable of changing the rate of a reaction without itself undergoing any net change.

Chrome – A term commonly used to indicate ore of chromium, consisting especially of the mineral chromite or chromium-bearing minerals, such as chrome mica or chrome diopside.

Coal – A readily combustible rock containing more than 50% by weight and more than 70% by volume of carbonaceous material, including inherent moisture.

Consumables – Includes any item, which is required for a manufacturing process, but does not necessarily form part of the end product. Items that are substantially or totally consumed during a manufacturing process are deemed to be consumables.

Contamination – Process whereby the chemical composition of magma is altered as a result of the assimilation of inclusions or country rock. A term describing metals and alloys with structures composed of more than one constituent.

Copper – This refers to a reddish metallic element that takes on a bright metallic lustre and is malleable, ductile, and a good conductor of heat and electricity.

Diamond – A form of pure carbon that occurs naturally as a clear, usually colourless, cubic crystal and is the hardest of all known minerals. It often occurs as octahedrons with rounded edges and curved surfaces. Diamonds form under conditions of extreme temperature and pressure. Diamonds are used in the jewellery industry and poorly formed diamonds are used in abrasives and industrial cutting tools. Diamond occurs in kimberlite pipes and dikes, also in river and beach placers.

Dimension stone – Any rock suitable for construction purposes, as distinguished from crushed stone or aggregate.

Downstream value addition – Involves a range of activities including large-scale capital intensive activities such as smelting, refining as well as labour intensive activities such as craft jewellery metal fabrication such as machinery and equipment manufacture.

Exploration – The search for mineral deposits and the work done to prove or establish the extent of a mineral deposit. A formal, systematic and standardised process subject to industry norms, which is initiated in search of mineral deposits including the work done to prove or establish the extent of the deposit and the economic mineability thereof.

Extraction – The process of mining and removal of valuable mineral resources from the earth through mining. Broadly, these processes involve selective mining or bulk mining then breaking down ore both mechanically (crushing) and chemically (decomposition), and separating the mineral from the associated gangue. Extractive metallurgy techniques might need to be employed to further upgrade the mineral. These extractive metallurgy techniques may be conveniently divided into physical metallurgy, pyrometallurgy, hydrometallurgy, and electrometallurgy.

Fluorspar – An isometric mineral, CaF_2 with perfect octahedral cleavage; transparent to translucent; and occurs in veins as a gangue mineral, in carbonate rocks, and an accessory in igneous rocks.

Fragmentation – The breakage of rock during blasting in which explosive energy fractures the solid mass into pieces. It also refers to the distribution of rock particle sizes after blasting.

Gas emissions – This refers to the release of gas, often methane, from the rock into the mine workings.

Geochemistry – The study of the relative and absolute abundances of the elements and their nuclides (isotopes) in the Earth. Geochemistry may be defined very broadly to include all parts of geology that involve chemical changes, or it may be focused more narrowly on the distribution of the elements.

Geophysics – A branch of physics dealing with the Earth, including its atmosphere and hydrosphere. It includes the use of seismic, gravitational, electrical, thermal, radiometric, and magnetic phenomena to elucidate processes of dynamic geology and physical geography, and makes use of geodesy, geology, seismology, meteorology, oceanography, magnetism, and other Earth sciences in collecting and interpreting Earth data. Geophysical methods have been applied successfully to the identification of underground structures in the Earth and to the search for structures of a particular type, as, for example, those associated with oil-bearing sands.

Gold – A dense isometric mineral, Au; commonly alloyed with silver or copper, possibly with bismuth, mercury, or the platinum-group metals; metallic yellow; soft and malleable; and resistant to corrosion. Occurs in veins and alluvial deposits and is often separated from rocks and other minerals by sluicing and panning operations. It is a good conductor of heat and electricity. It is used in coinage, jewellery, decoration, dental work, plating, and for coating certain space satellites. It is a standard for monetary systems in many countries.

Grinding – The process of erosion by which rock fragments are worn down, crushed, sharpened, or polished through the frictional effect of continued contact and pressure by larger fragments.

Heavy Metals – In exploration geochemistry, principally zinc, copper, cobalt, and lead, but under special conditions including one or more of the following metals: bismuth, cadmium, gold, indium, iron, manganese, mercury, nickel, palladium, platinum, silver, thallium, and tin.

Iron – The fourth most abundant element by weight making up the crust of the Earth. The most common ore is hematite, Fe_2O_3, from which the metal is obtained by reduction with carbon. Iron is the cheapest and most abundant, useful, and important of all metals.

Lead – A bluish-white metal of bright lustre, very soft, highly malleable, ductile, and a poor conductor of electricity; very resistant to corrosion; Pb. It rarely occurs in native form; chiefly obtained from galena (PbS). Lead is used in storage batteries, cable covering, plumbing, ammunition, antiknock gasoline, radiation shielding, and to absorb vibration. Other lead compounds are used in paints, fine glass, and lenses. Environmental concern with lead poisoning has resulted in a U.S. national program to reduce the concentration of lead in gasoline.

Limestone – A carbonate sedimentary rock containing more than 95% calcite and less than 5% dolomite. Common minor constituents include silica (chalcedony), feldspar, clays, pyrite, and siderite. It is also a general term used commercially (in the manufacture of lime) for a class of rocks containing at least 80% of the carbonates of calcium or magnesium and which, when calcined, gives a product that slakes upon the addition of water.

Magnesium – A light, silvery-white, and fairly tough metal. It is found in large deposits in the form of magnesite, dolomite, and other minerals. Readily ignites upon heating. It is used in flashlight photography, flares, and pyrotechnics, including incendiary bombs. Its alloys are essential for airplane and missile construction.

Manganese – A grey-white, hard, brittle metallic element, Mn. Manganese does not occur uncombined in nature, but its minerals are widely distributed. Pyrolusite (MnO_2) and rhodochrosite ($MnCO_3$) are the most common minerals. It is used to form many important alloys, especially with steel, aluminium, and antimony; used in dry cells and glass, and in the preparation of oxygen, chlorine, and medicines.

Mineral Processing – The dry and wet crushing and grinding of ore or other mineral-bearing products for the purpose of raising concentrate grade; removal of waste and unwanted or deleterious substances from an otherwise useful product; separation into distinct species of mixed minerals; chemical attack and dissolution of selected values. Among the methods used are hand sorting (including radio activation and fluorescence); dense media separation; screening and classification; gravity treatment; magnetic separation at low or high intensity; leach treatment, perhaps using pressure and heat; and (universally) froth flotation.

Mineral – A naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties.

Mining – The science, technique, and business of mineral discovery and exploitation. Strictly, the word connotes underground work directed to severance and treatment of ore or associated rock. Practically, it includes opencast work, quarrying, alluvial dredging, and combined operations, including surface, underground and ore treatment.

Nickel – An isometric mineral, elemental Ni. It takes on a high polish and is a fair conductor of heat and electricity. It is used for making stainless steel and other corrosion-resistant metals and is chiefly valuable for the alloys it forms. It is also used extensively in coinage, in desalination plants for converting seawater into fresh water, and in making nickel steel for armour plate and burglar-proof vaults.

Ore – The naturally occurring material from which a mineral or minerals of economic value can be extracted profitably or to satisfy social or political objectives. The term is generally but not always used to refer to metalliferous material, and is often modified by the names of the valuable constituent; e.g., iron ore.

Palladium – A soft, ductile, steel-white metallic element of the platinum group metals (symbol, Pd). It is found along with platinum and other metals of the platinum group in placer deposits; also found associated with nickel-copper deposits. It is used as a catalyst, in dentistry, watch making, surgical instruments, and electrical contacts.

Phosphates – Any mineral containing essential tetrahedral phosphate, $(PO_4)^{3}$, e.g., apatite, amblygonite, or monazite. The source materials for phosphate are marine phosphorite and, less commonly, guano and apatite-rich igneous rocks.

Platinum – It is a malleable and ductile silvery-white metal, when pure. Symbol: Pt. Occurs native, accompanied by small quantities of iridium, osmium, palladium, ruthenium, and rhodium. It is used in catalysts, jewellery, wire, vessels for laboratory use, and in many valuable instruments including thermocouple elements.

Precious Metals – Any of several relatively scarce and valuable metals, such as gold, silver, and the platinum-group metals.

Remote Sensing – This is a branch of geophysics. Satellite images of the surface are acquired and interpreted using infrared and visible wavelengths of light.

Rhodium – An element of the platinum group, Symbol: Rh.

Rock Stress – The problem of determining the stresses that exist in the Earth's crust has long been of interest to engineers and geologists. Many mining problems are directly concerned with stresses that may cause mine openings to collapse. Two phases of occurrence of rock stresses are important: the stresses existing in the rock before the excavation of the mine openings; i.e., the free field stress and the indirect stresses caused by the mine openings.

Royalty – A lease by which the owner or lessor grants to the lessee the privilege of mining and operating the land in consideration of the payment of a certain stipulated royalty on the mineral produced.

Flocculation – The process by which a number of individual, minute suspended particles are tightly held together in clot-like masses, or are loosely aggregated or precipitated into small lumps, clusters, or granules; e.g., the joining of soil colloids into a small group of soil particles, or the deposition or settling out of suspension of clay particles in salt water.

Side stream - Refers to infrastructure (e.g. power, logistics etc.) research and development, human resource development and inputs such as capital goods, consumables and services.

Silicon – A non-metallic element that is the second most abundant on Earth, being exceeded only by oxygen. Symbol, Si. Silicon is not found free in nature, but occurs as the oxide and silicate. Sand, quartz, rock crystal, amethyst, agate, flint, jasper, and opal are some of the forms in which the oxide appears. Hornblende, orthoclase, kaolin, and biotite are a few of the numerous silicate minerals. Used in the electronics and space-age industries; used to make concrete, brick, and glass. Miners often develop a serious lung disease, silicosis, from breathing large quantities of the dust.

Silver – A white metallic element that is very ductile and malleable, Symbol (Ag). Occurs native and in ores such as argentite and horn silver; lead, lead-zinc, copper, gold, and copper-nickel ores are its principal sources. Used for jewellery, photography, dental alloys, and coinage.

Slime – Extremely fine sediment (#200 mesh), produced in the processing of ore or rock, especially phosphate rock, which remains suspended in water indefinitely. It consists chiefly of clay. Primary slimes are extremely fine particles derived from ore, associated rock, clay, or altered rock. They are usually found in old dumps and in ore deposits that have been exposed to climatic action; they include clay, alumina, hydrated iron, near-colloidal common earths, and weathered feldspars. Secondary slimes are very finely ground minerals from the true ore.

Tailings – The gangue and other refuse material resulting from the washing, concentration, or treatment of ground ore and is regarded as too poor to merit further washing.

Titanium – A silvery-gray or iron-gray, metallic element, symbol, Ti. Found in nature only in combined form; occurs chiefly in ilmenite ($FeTiO_3$), and in rutile and titanite. Light, strong and corrosion resistant with a high melting point. Used as an alloying agent with aluminium, molybdenum, manganese, iron, and other metals. Used in aircraft and missiles and has potential for use in desalination plants.

Effluent – A liquid, solid, or gaseous product, frequently waste, discharged or emerging from a process.

Uranium – A radioactive, silvery-white, metallic element, symbol, U. It occurs in numerous minerals such as pitchblende, uraninite, carnotite, autunite, uranophane, davidite, and tobernite. It is also found in phosphate rock, lignite, and monazite sands and associated with Witwatersrand gold. Uranium and its compounds are highly toxic, both chemically and radiological. Uranium is of great importance as a nuclear fuel; it is used as ballast for missile re-entry vehicles, as a shielding material, and for production of high-energy X-rays.

Vanadium – A grey or white malleable, ductile, metallic element. Symbol, V. Found in about 65 different minerals, among which are carnotite, roscoelite, vanadinite, and patronite; also found in phosphate rock, certain iron ores, and some crude oils. About 80% of the vanadium now produced is used as a ferrovanadium or as a steel additive; it is also used in ceramics, as a catalyst, and in the production of a superconductive magnet.

Vermiculite – A monoclinic mineral; part of the mica group. It expands 6 to 20 times by thermal exfoliation and occurs in clay sizes in soils and as crystals and megacrysts in ultramafic rocks. Used as a refractory material, for insulation and for packaging.

Zinc – The native metallic element, Zn. Employed to form numerous alloys with other metals including brass, nickel silver, commercial bronze, spring brass, soft solder, and aluminium solder. Used extensively by the automotive, electrical, and hardware industries.

Zirconium – A greyish-white lustrous metallic element. Symbol, Zr. Occurs widely, but only in combined form, especially in the minerals zircon, ($ZrSiO_4$), and baddeleyite, (ZrO_2). Uses include resisting corrosion, as a structural material in nuclear reactors, as an alloying agent, deoxidizer, bonding agent, refractory material, and in low-temperature superconductive magnets.