PROGRESS MADE BY THE SOUTH AFRICAN LIGHT METALS DEVELOPMENT NETWORK

Oliver Damm[1] and Willie du Preez[1]

[1]CSIR, Meiring Naude Road, Pretoria, 0001, South Africa

Abstract

Through focused investment by the CSIR, the South African Innovation Fund, the Automotive Industry Development Centre and the Department of Science and Technology over the past eight years, the national Light Metals Development Network has been established and grown into a well aligned collaborative research and development programme. The research and development focus has been primarily on Aluminium and Titanium technologies as applied in the automotive and aerospace industry sectors, with the latter growing in prominence over the past three years. Since 2009 the Titanium related research and development activities have been consolidated in a Titanium Centre of Competence.

This paper provides an overview of the current status of the programme, the R&D focus areas, the collaborating entities and the industry involvement. It also highlights some of the significant achievements of the network and notable outputs produced. The Titanium Centre of Competence as a vehicle for strengthening industrial research and innovation capabilities in specific fields of technology is discussed and some initial experiences are shared.

Introduction

South Africa has a significant and vibrant light metals industry, centred primarily on aluminium. The country produces some 880,000 tons of primary aluminium per annum in two smelters located in Richardsbay, with a further smelter expected to be developed by Alcan over the coming years (initial capacity 350kt p.a.). Some 180,000 tons or 20% of primary material are converted for local use in the form of rolled products, extrusions, and castings. The main industry sectors are transport (particularly automotive wheels and other components), packaging, and building and construction, in that order.

The industry faces a number of significant challenges at present. Rapidly rising electricity costs in South Africa are impacting negatively on the international competitiveness of both the primary and downstream industries. Downstream industry sectors are comparatively small in global terms, which makes it difficult to achieve the volumes and economies of scale that are required to compete effectively and to justify substantial investments into new production equipment and technologies. Export oriented sectors such as the automotive components industry are exposed to currency volatility, stiff competition from large manufacturing locations, particularly in Asia, and the geographical remoteness of South Africa relative to the major end user markets.

The presence of a strong local technology capability is vital to support domestic light metals manufacturers and to expand the competitiveness of the industry.

The CSIR has had a long standing relationship with the industry as a technology partner, focusing mainly on the development of improved primary aluminium production processes, as well as downstream manufacturing process development. However, these activities historically occurred on an ad hoc basis with little strategic foresight or coordination with other technology providers. It is within this context that the Light Metals Development Network (LMDN) as well as other technology support initiatives have been developed.

Strategic Framework

Figure 1 below illustrates a map of the national strategic interventions in South Africa aimed at the metals industry, in the form of a conceptual R&D value chain.

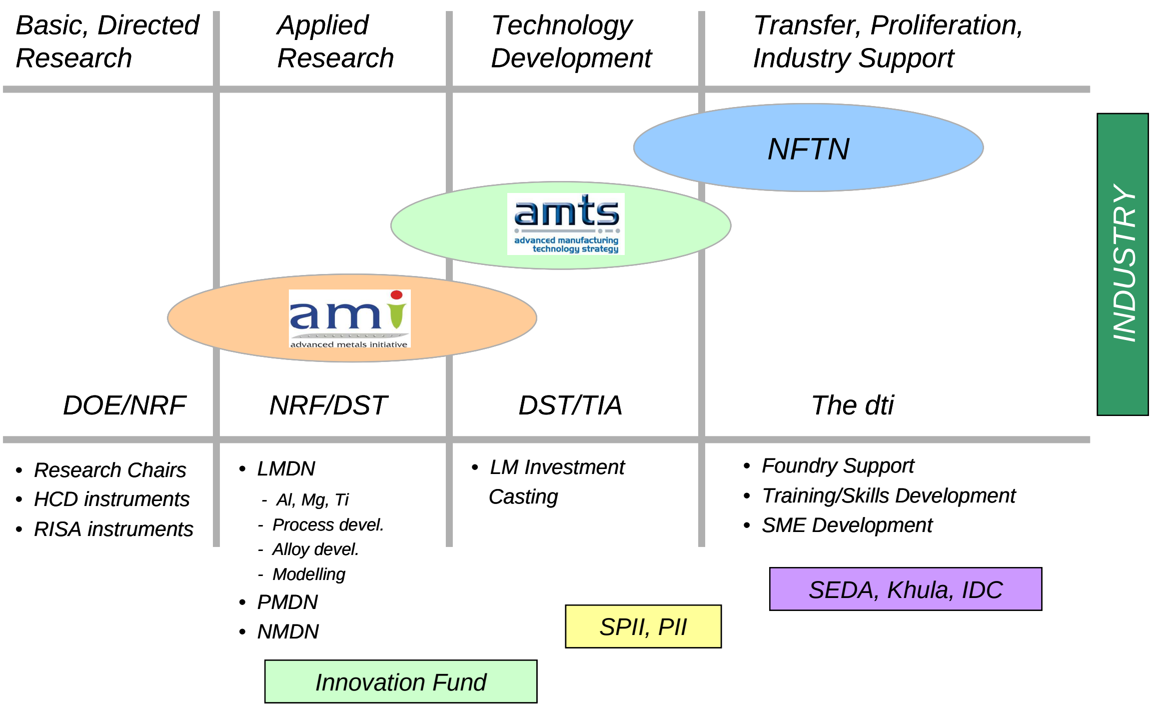


Figure 1. Strategic interventions in South Africa, mapped on a conceptual metals R&D value chain.

The LMDN forms part of a broader Advanced Metals Initiative (AMI) and is currently focused on conducting applied research in the fields of aluminium and titanium. As the name suggests, the LMDN operates in a network mode, involving seven universities as well as other science councils. The Advanced Manufacturing Technology Strategy (AMTS) is focused on the development of advanced manufacturing technologies and also incorporates a Light Materials Flagship programme. Finally, the National Foundry Technology Network (NFTN) was established in 2008 with a view to supporting the foundry industry with day-to-day consulting and technology support.

Funding support for the AMI and the AMTS is sourced primarily from the National Research Foundation (NRF) and the Department of Science and Technology (DST), which are focused on supporting directed and applied research as well as technology development. Universities also receive some incentive funding from the Department of Education (DOE), based on research outputs, such as peer-reviewed publications. The Innovation Fund supports product and process innovations that lead to commercialization of technology. Seed funding for the NFTN over a period of three years has been sourced from the Department of Trade and Industry (the dti), in line with this department's mandate to develop supply side support measures for local industry. To ensure relevance and responsiveness to industry needs, the NFTN is managed by a steering committee that includes a number of representatives from the foundry industry. Technology transfer and industry development projects could qualify for funding from the Special Programme for Innovation in Industry (SPII) and the Programme for Innovation in Industry (PII) supported by the dti.

Collectively, these initiatives comprise a metals R&D value chain which provides for the support of basic research, through technology development and transfer (innovation), to day-to-day industry support. Efforts are on-going to identify larger strategic technology thrusts within this value chain, and to establish significant, multi-year research and development programmes accordingly. This framework provides a guide for the coordination of the activities of network participants. The coordination further serves to align the discretionary investments of network players, thereby leveraging research funding and promoting the development of meaningful and sustainable competencies.

Research Focus Areas

The fundamental objectives of the initiatives described above can be summarised as follows:

- To enhance industry competitiveness and increase local manufacture of beneficiated light metal products;
- To increase local technology capacity and capabilities in the field of light metals, including the development and transfer of novel and proprietary technologies;
- To develop effective knowledge networks; and
- Human capacity development.

A summary of the research and development focus areas for the various initiatives is provided in Table 1. It will be seen that substantial effort is directed at the development of proprietary process technologies for downstream manufacture of aluminium and titanium components. These are targeted towards the automotive industry in the case of aluminium and the aerospace and biomedical industries in the case of titanium.

The development of new materials requires a long-term view since the acceptance of a new material in the marketplace is typically a lengthy process. For this reason the LMDN only focuses on very selective materials development activities, such as those directed at titanium powder metallurgy, which is believed to be a significant future growth area.

Finally, the NFTN activities are focused on shop-floor training programmes, foundry performance benchmarking and improvement, and the analysis and reduction of energy consumption in foundries.

Table 1. Summary of research and development focus areas across the metals value chain

Initiative	Materials Development	Process Technology	Product Development	Competitiveness Improvement
LMDN	• Titanium powders - high energy milling • Binders for Ti powder metallurgy	• Ti Powder Injection Moulding • CSIR Aluminium Rheocasting Process • Heat Treatment of Al alloys • Friction Stir Welding of Al and Ti • Laser cladding of Al • Additive fabrication of Ti components	• Rheocast automotive components (demo) • Ti biomedical components by additive fabrication	• Tooling design and optimisation for Al die casting • Novel tooling for plastics industry using high performance aluminium alloys
AMTS		• Ti investment casting • Counter gravity casting of Al and Mg • Ti high performance machining	• Direct pattern / shell manufacture by rapid prototyping techniques	
NFTN				• Foundry training programme • Benchmarking of firms • Energy usage in foundries

Some Achievements

Light Metals Development Network (LMDN)

A novel rheocasting process for aluminium alloys has been developed over a number of years, culminating in the establishment of an industrial-scale, robotized production cell centred around a 630 ton high pressure die casting machine (Figure 2). The rheocasting process essentially involves the controlled electromagnetic stirring and cooling of an aluminium melt to a temperature between the solidus and liquidus, thus producing a semi-solid billet. The billet is inserted into a high pressure die casting machine by means of a robot and processed into the desired shape. The process has been shown to produce superior integrity (i.e. reduced porosity) and improved mechanical properties compared to conventional high pressure die casting. Also, some wrought alloys have been successfully processed in this way. An automotive demonstration part has been successfully re-designed to suit rheocasting, and a short production run has been demonstrated. The technology is protected by means of a number of patents, and is now entering the commercialization phase [1].

Significant work has also been done to understand and optimise the heat treatment of rheo-processed aluminium components [2]. Some of this work is discussed in other papers at the present conference, and will thus not be elaborated on here. Similarly, titanium powder metallurgy work is in the initial stages of development and is discussed in a separate paper.

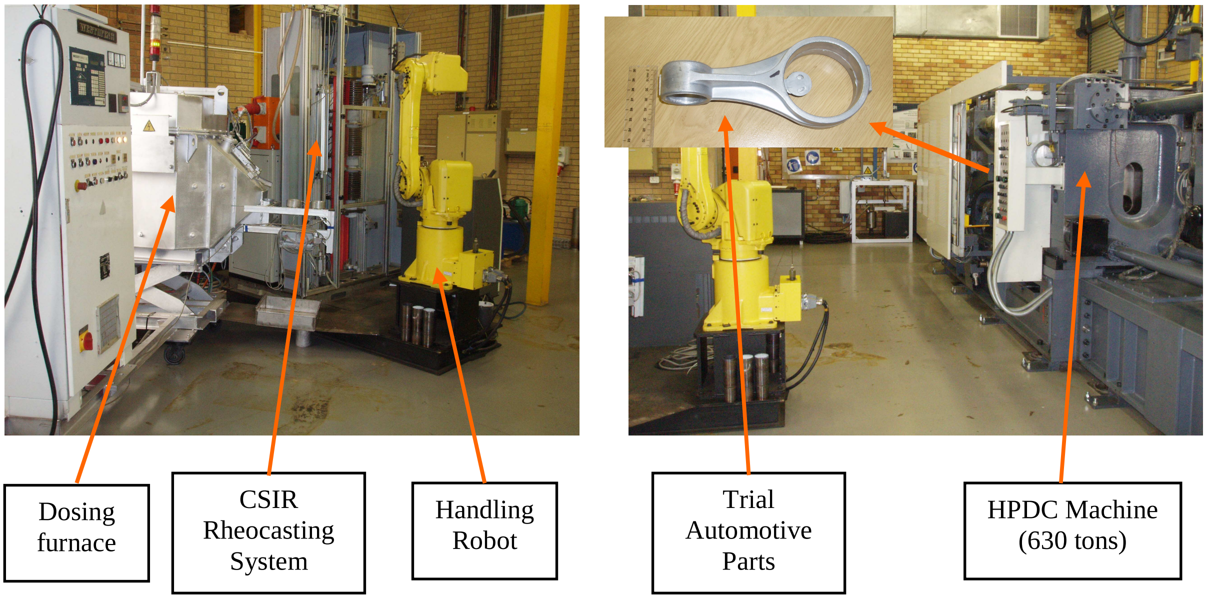
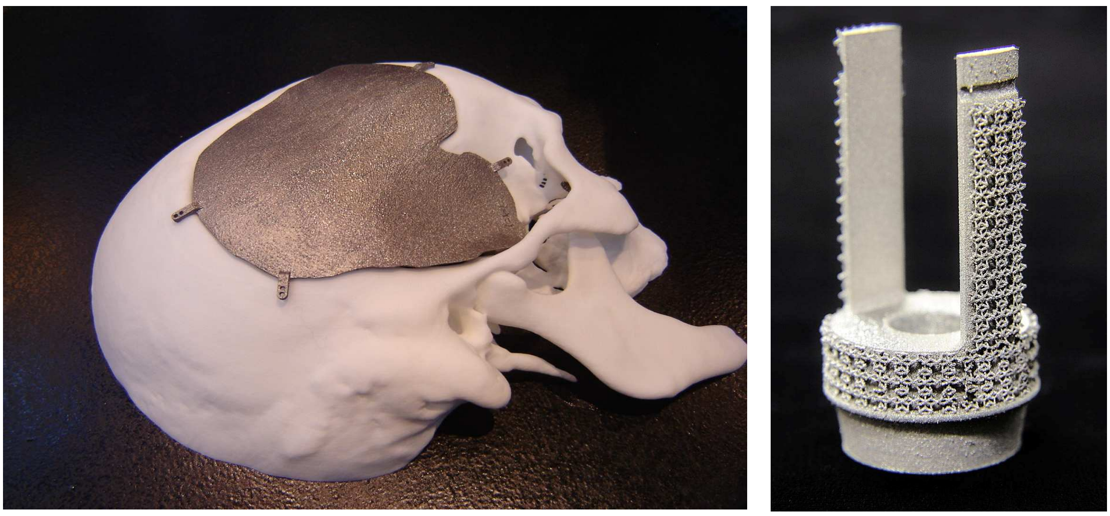


Figure 2. CSIR rheocasting prototype production cell.

Exciting recent developments in the field of additive fabrication of components by means of laser sintering of titanium powder has resulted in the capability to rapidly design and produce customized titanium biomedical implants. [3,4] Figure 3 shows two typical examples, i.e. a titanium plate to repair a skull defect, and an implant to repair a fractured elbow.



(a) (b)

Figure 3. Titanium biomedical implants produced by additive fabrication techniques: (a) skull plate, (b) elbow implant

The level of complexity that can be achieved is illustrated further in Figure 4, which shows a highly complex pelvic and hip reconstruction that was achieved by combining 3-dimensional computer tomography (CT) scanning, rapid prototyping and machining techniques.

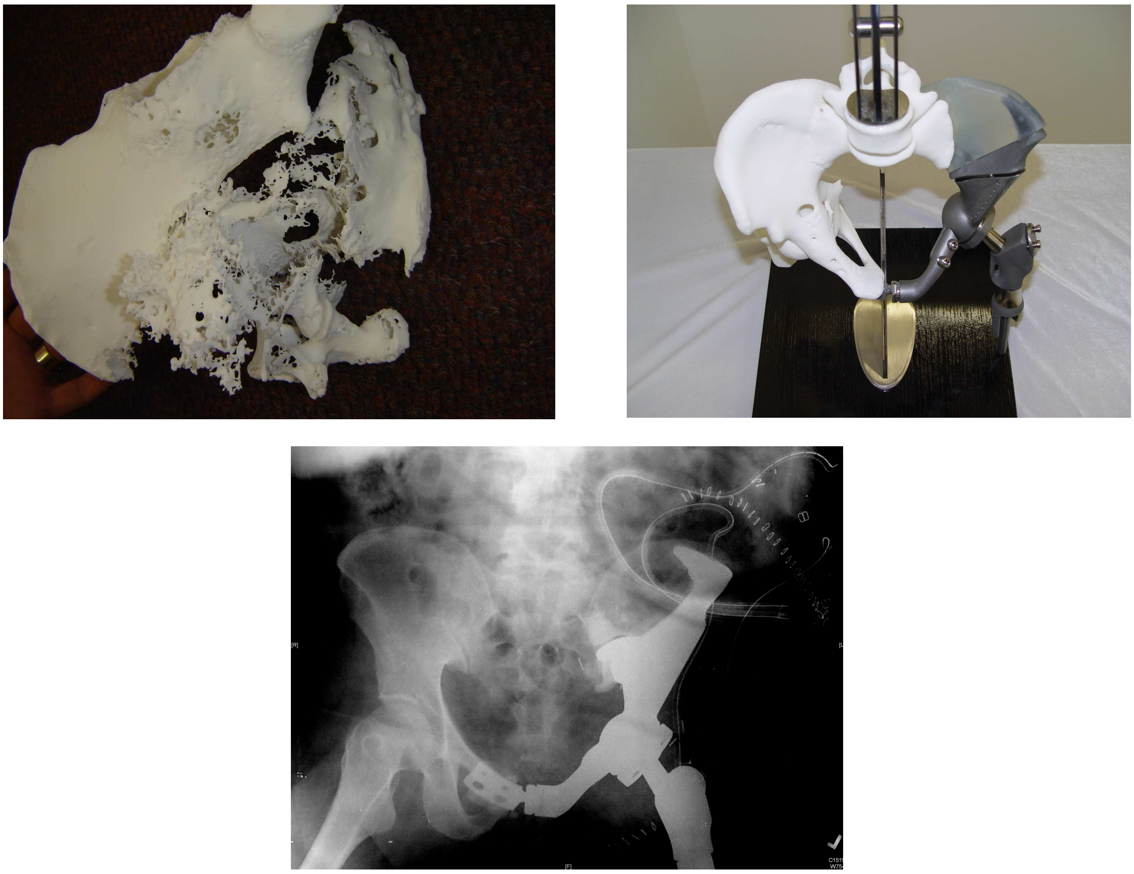


Figure 4. Pelvic and hip reconstruction showing a rapid prototype of the diseased pelvic area, the titanium implant, and an x-ray of the reconstruction

AMTS

One of the main focus areas under the AMTS has been the development of investment casting technology for titanium components, typically for aerospace applications. Since the CSIR currently lacks a skull melter, a ceramic crucible for use in a conventional industrial scale vacuum melting unit has been developed, along with ancillary technology packages such as melting and pouring techniques and investment shell generation processes. The technology package has been successfully demonstrated on an aerospace component (Figure 5).

Human Resource Development

Through the networks established with universities and other science councils, some 30 studentships and bursaries, as well as 3 post-doctoral fellowships, have been awarded through the LMDN and AMTS. Of these, some 30% are at graduate and honours level, 40% at masters degree level, and 14% at doctoral level.

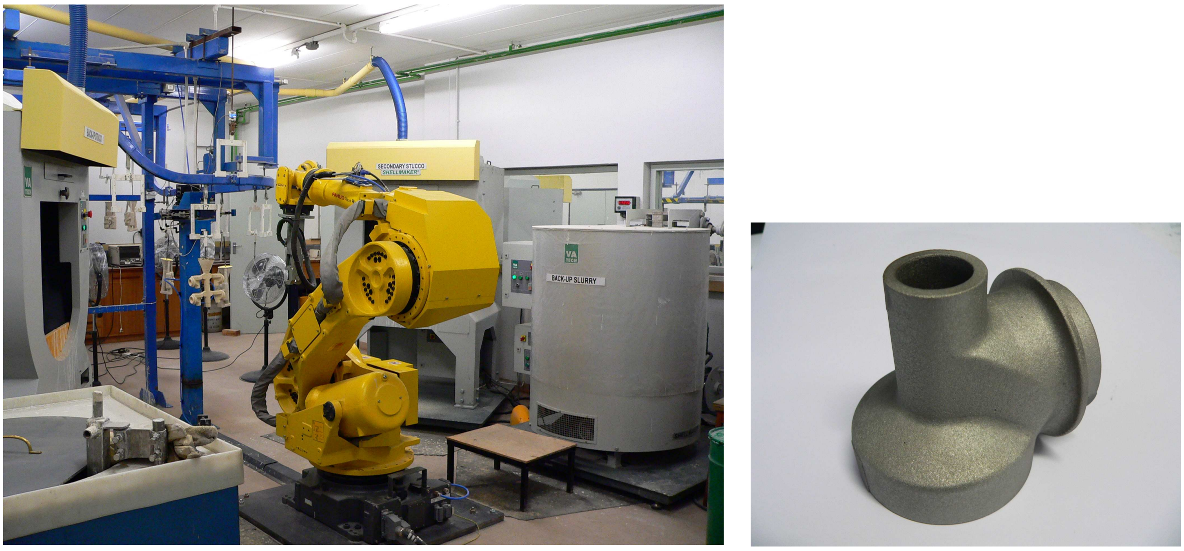


Figure 5. CSIR investment casting facility and demo titanium aerospace part

Titanium Centre of Competence

From 2009, the titanium R&D activities will be consolidated into a Titanium Centre of Competence. A Centre of Competence is defined as a collaborative technology development consortium comprising Science Councils, Academic Institutions and Industry. It is guided by national priorities and relies on harnessing the resources, capabilities and synergies of all consortium partners, with clear research objectives in pursuit of products and services with commercial or public-good potential in response to market opportunity, failure and/or socio-economic challenges. The conceptual model for the centre is shown in Figure 6.

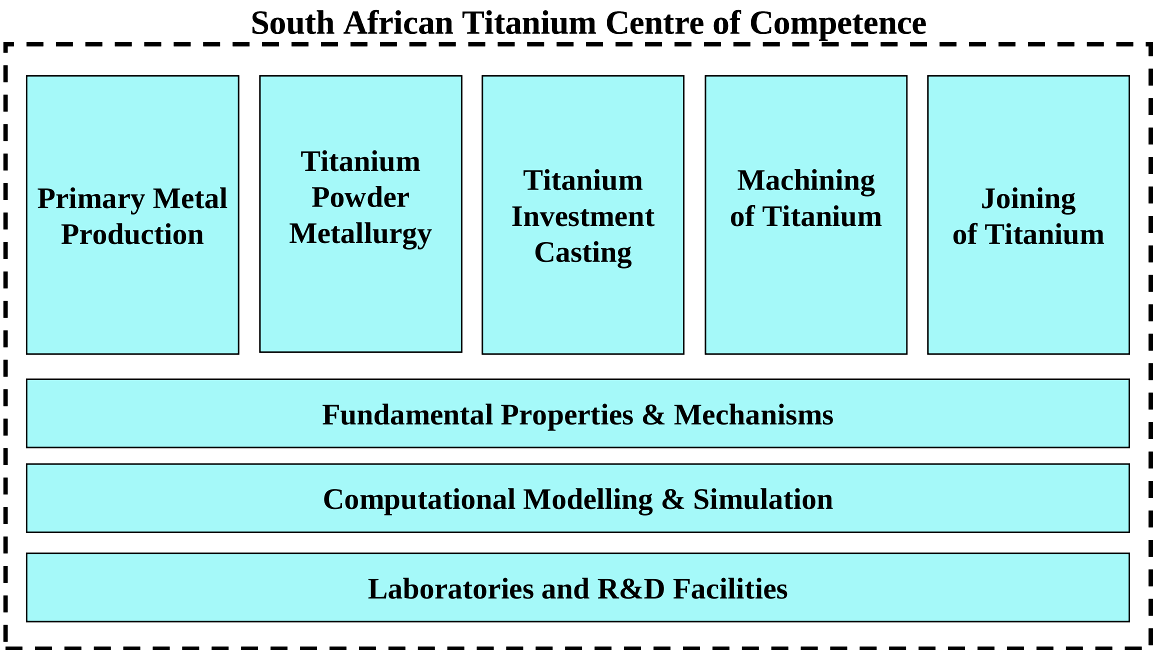


Figure 6. Conceptual model of Titanium Centre of Competence

The anticipated research focus areas cover the titanium value chain from the production of the primary metal through to near net shape processing and joining of titanium. The activities will be underpinned by strong competencies in the fundamental metallurgy of titanium, computational modeling and simulation, and appropriate R&D facilities.

The centre will operate in a virtual network mode, with the strong involvement of universities in particular in the areas of more fundamental directed research and human resource development. The established network is illustrated in Figure 7, comprising 9 universities and 3 national science councils.

It is also envisaged that the centre will be managed through a coordinating office in the newly established national Technology Investment Agency (TIA), rather than be located at one of the network players. The intention in this regard is to avoid undue influence on the Centre agenda by any one network player.

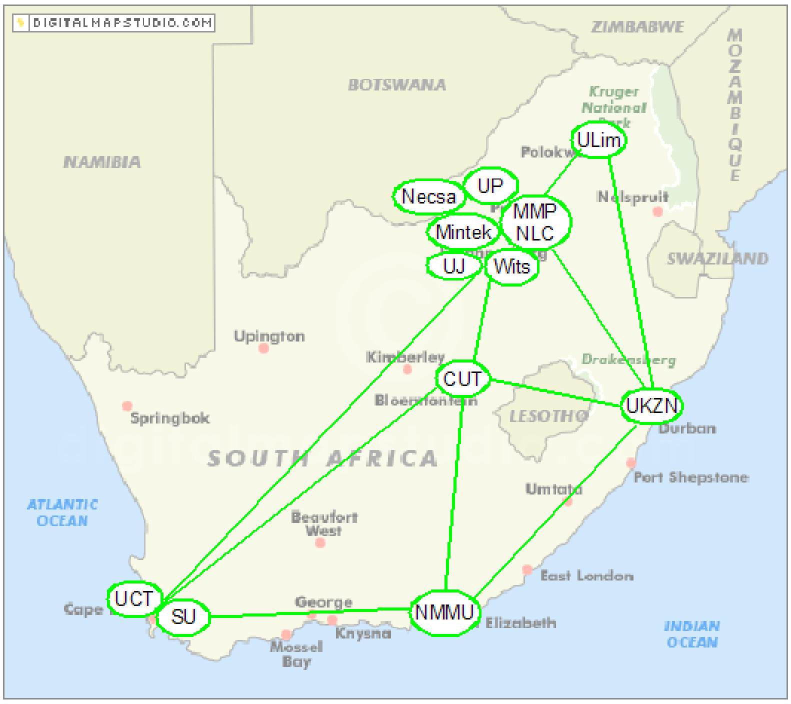


Figure 7. Titanium Centre of Competence network.

Concluding Remarks

The development of a national agenda and associated R&D initiatives has greatly improved the focus and the scale of light metals research in South Africa. Subsequent establishment and development of research networks between government, national science councils, and universities has been found to be a challenging business, but rewarding in the sense that human and financial resources can be leveraged towards a common goal. Moreover, the involvement of universities is critical for the development of human resources, which is of vital importance given South Africa's relative lack of skills.

The establishment of a Titanium Centre of Competence is a further milestone in the focusing of light metals research in South Africa. Through the consolidation of titanium related research and the strengthening of the established R&D network, a strong national capability in the selected value chain technologies can be achieved. Independent management of the Centre will be an important aspect in order to avoid undue influence on the Centre agenda by any one network participant.

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