Development of a Technology Transfer and an Intellectual Property Strategy for Titanium Machining

by

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering Management in the Faculty of Engineering at Stellenbosch University

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March 2015

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

South Africa holds the second largest share of the world's titanium mineral deposits. However, there is no capacity for the development of titanium metal, mill products or components. It is at these stages of development that most of the value is added. For this reason, the Department of Science and Technology (DST) has been undertaking a research-led industrialisation initiative. The aim of this initiative is to establish a titanium industry strategy within South Africa. This research comes at a time when the demand for titanium, particularly from the commercial aerospace and biomedical sectors is growing rapidly.

A South African industrial strategy framework has been developed by the DST to deliver titanium related competencies across the entire titanium value chain. One of the key building blocks within the strategy framework is targeted at the machining of titanium metal. This is a core competence required for the manufacture of finished titanium products. This research is fully aligned with the Advanced Manufacturing Technology Strategy (AMTS) and its objective of improving industry competitiveness via the development of advanced manufacturing technologies, as well as to the objectives of the Titanium Centre of Competence (TiCoC), whose mission is to develop and commercialise the technology building blocks required for the establishment of a titanium industry in South Africa.

In order to implement the titanium industry strategy successfully in South Africa, all research being conducted in this field needs to be transferred to industry as well as protected. This is the focus of this thesis and is achieved through the development of technology transfer (TT) strategy as well as an intellectual property (IP) strategy for titanium machining. Without a TT strategy, the technological developments which are made might not be successfully implemented into industry as intended. An IP strategy is equally as important as, without one, entire research and development projects can be lost to those seeking to take advantage of incorrectly protected IP.

To develop the TT and IP strategies, substantial information on the basics of these fields was considered. Titanium machining relevant information, such as contract details, industrial partnerships as well as the level of development which the research had achieved upon starting this study was also considered. Together this information created a solid foundation for decision making with regards to how both IP and TT should be handled for the titanium machining research initiative. Each new technology developed, along with its respective IP needs to be considered individually, as the scenarios for both its protection and transfer into industry will be in some way unique. As such, the strategies developed within this report attempt to provide a general outline for the decision making process for any situation which might arise.

Ultimately both strategies are represented within this thesis. In order to take the research presented in this thesis further, the development of an IP portfolio is suggested allowing for decisions to be made with regards to technology specific IP outputs. For the technology transfer further implementation of tests for validation purposes at the industrial partners is recommended, in order to begin to develop an understanding of their environments and capabilities.

Opsomming

Suid-Afrika beskik oor die wereld se tweede grootste titaaan mineraalafsetting, maar daar is geen kapasiteit vir die ontwikkeling van titaan metaal, milj produkte of komponente nie. Dit is op hierdie stadium van ontwikkeling waar die meeste waarde toegevoeg word. Om hierdie rede is die Departement van Wetenskap en Tegnologie (DWT) besig met ‘n navorsingsgedrewe industrialisering inisiatief. Die doel van hierdie inisiatief is om 'n titaan bedryfstrategie in Suid-Afrika te vestig. Hierdie navorsing vind plaas op ‘n tydstip waar die vraag na titaan, veral vanuit die kommersiële ruimte- en biomediese sektore, vinnig groei.

'n Suid-Afrikaanse industriële strategie raamwerk is ontwikkel deur die DWT om titaan verwante vaardighede te lewer oor die hele titaan waardeketting. Een van die belangrikste boustene binne die strategiese raamwerk is gemik op die bewerking van titaan metaal. Dit is die kernbevoegdheid wat benodig word vir die vervaardiging van voltooide titaan produkte. Hierdie navorsing is ten volle belyn met die “Advanced Manufacturing Technology Strategy” (AMTS) en sy doelwit van verbetering van die bedryfsmededingendheid via die ontwikkeling van gevorderde vervaardigingstegnologie, asook die doelwitte van die “Titanium Centre of Comptetence” (TiCoC), wie se missie dit is om die tegnologiese boustene wat nodig is vir die vestiging van 'n titaan bedryf in Suid-Afrika te ontwikkel en te komersialiseer.

Ten einde die titaan bedryf strategie suksesvol in Suid-Afrika te implementeer, moet alle navorsing in hierdie veld beskerm word en daarna na die bedryf oorgeplaas word. Dit is dan die fokus van hierdie tesis, wat bereik word deur die ontwikkeling van ‘n IP strategie asook ‘n tegnologie oordragstrategie vir titaan masjinering. Sonder die nodige intellektuele eiendom (IP) beskermingstrategie, kan hele navorsing- en ontwikkeling projekte verloor word deur diegene wat voordeel wil trek uit IP wat nie korrek beskerm is nie. ‘n Tegnologie oordragstrategie is ewe belangrik aangesien, in die afwesigheid hiervan, die ontwikkelings wat gemaak word, dalk nie suksesvol geïmplementeer sal word in industrie soos bedoel nie.

Om die IP strategie te ontwikkel, is omvattende inligting oor die basiese beginsels van IP beskerming en bestuur oorweeg. Tersaaklike inligting oor titaan verwerking soos, kontrak besonderhede, industriele venootskappe asook die vlak van ontwikkeling wat die navorsing alreeds bereik het met die aanvang van hierdie studie, is in ag geneem. Saam het hierdie inligting ‘n stewige fondament geskep vir besluitneming ten opsigte van die toepassing en die hantering van beide IP asook die oordrag van tegnologie in die titaanverwerking navorsings inisiatief. Elke nuwe tegnologie wat ontwikkel word, tesame met die betrokke IP benodighede, moet individueel oorweeg word, aangesien die scenario vir beide die IP beskerming en oordrag van die tegnologie na industrie unieke aspekte sal hê. As sodanig poog die strategie wat ontwikkel is binne hierdie verslag, 'n algemene raamwerk te bied vir die besluitnemingsproses vir enige situasie wat mag ontstaan.

Beide strategieë is in hierdie tesis aangespreek. Die rigting vir toekomstige werk dui daarop dat ‘n IP portfolio saamgestel moet word wat voorsiening maak vir tegnologies-spesefieke besluite ten opsigte van IP uitsette. Ten opsigte van tegnologie oordrag, word verder aanbeveel dat toetse vir die validasie by venote in industrie ingestel word, ten einde begrip te ontwikkel vir hulle omgewings en vermoens.

Acknowledgements

I would like to express my sincere gratitude to the following people:

My supervisor, Professor D.M Dimitrov for taking time out of his busy schedule to provide me with valuable feedback. Your help is extremely appreciated as is your positive attitude towards my work.

Konrad Von Liepzig, for assisting me in determining the direction and scope of my research.

My family, for providing me with the opportunity to study further, and for their love and support throughout this project.

InnovUS, the technology transfer office at Stellenbosch University, for their guidance and suggestions with regards to my work. In particular I would like to thank Doris Peters for her enthusiasm and assistance.

Aerosud, for their friendly attitude and for answering any questions I had during my visit to their premises.

My colleague, Pieter Conradie for his assistance and for taking time out of his schedule to complete an InnovUS disclosure form for me.

Paul Muscat of Adams and Adams attorneys for the information he provided me with regards to patent registration.

Professor Anton Doubell for assisting me with the translation of my abstract into Afrikaans.

My friends, particularly my fellow engineers Graziano Marcantonio and Piotr Rokita, for their support throughout this project.

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Chapter 1. Introduction

1.1 Background and Problem Statement

The South African titanium industry strategy framework has been formulated by the DST (Department of Science and Technology) with a view to deliver titanium related competencies across the entire titanium value chain, from production of titanium minerals to the manufacture of final products as can be seen in Figure 1.

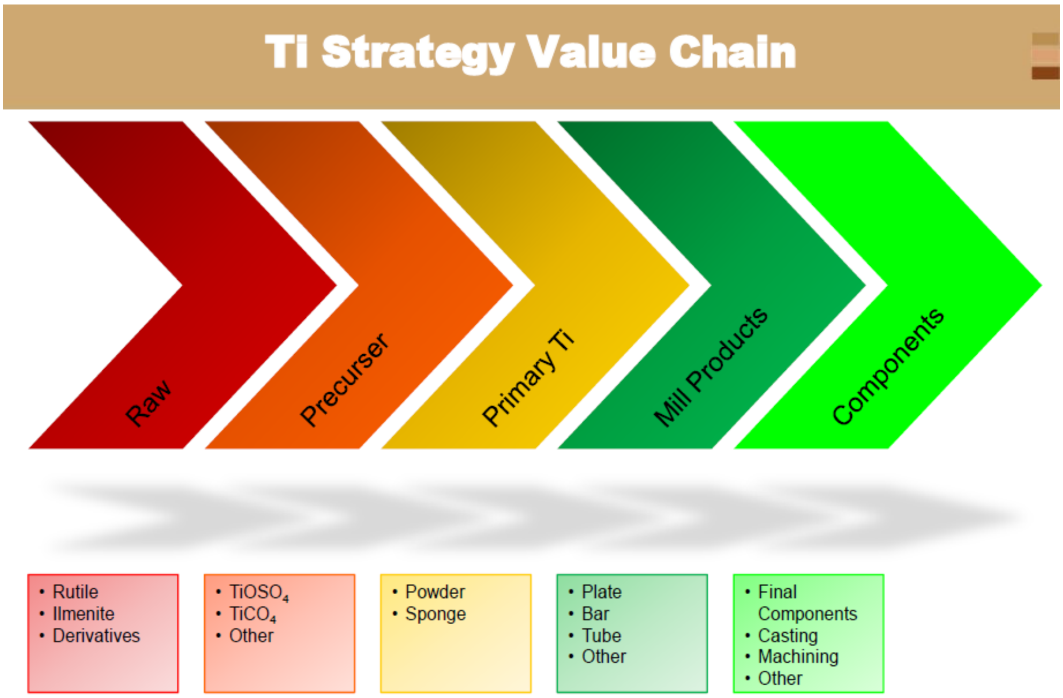

Figure 1: Titanium value chain

The development work required to implement this industrial strategy is carried out under the auspices of a Titanium Centre of Competence (TiCoC), hosted by the CSIR, whose mission is to develop and commercialise the technology building blocks required for the establishment of a titanium industry in South Africa, with both upstream and downstream manufacturing activities. One of these key building blocks is targeted at the machining of titanium metal. This is a core competence required for the production of finished products for the automotive, aerospace, and biomedical industries. The TiCoC model can be seen in Figure 2, and shows the different technology building blocks.

Stellenbosch University, in collaboration with other universities as well as Fraunhofer Institute for Machining Tools and Forming Technology (hereafter referred to as Fraunhofer) in Germany, are conducting research into titanium machining with funding provided by the South African government. The government is being represented by the DST. This research is for the benefit of the South African economy and will be implemented through the local industrial partners involved, who will be receiving the technology and IP developed in return for their involvement in the research.

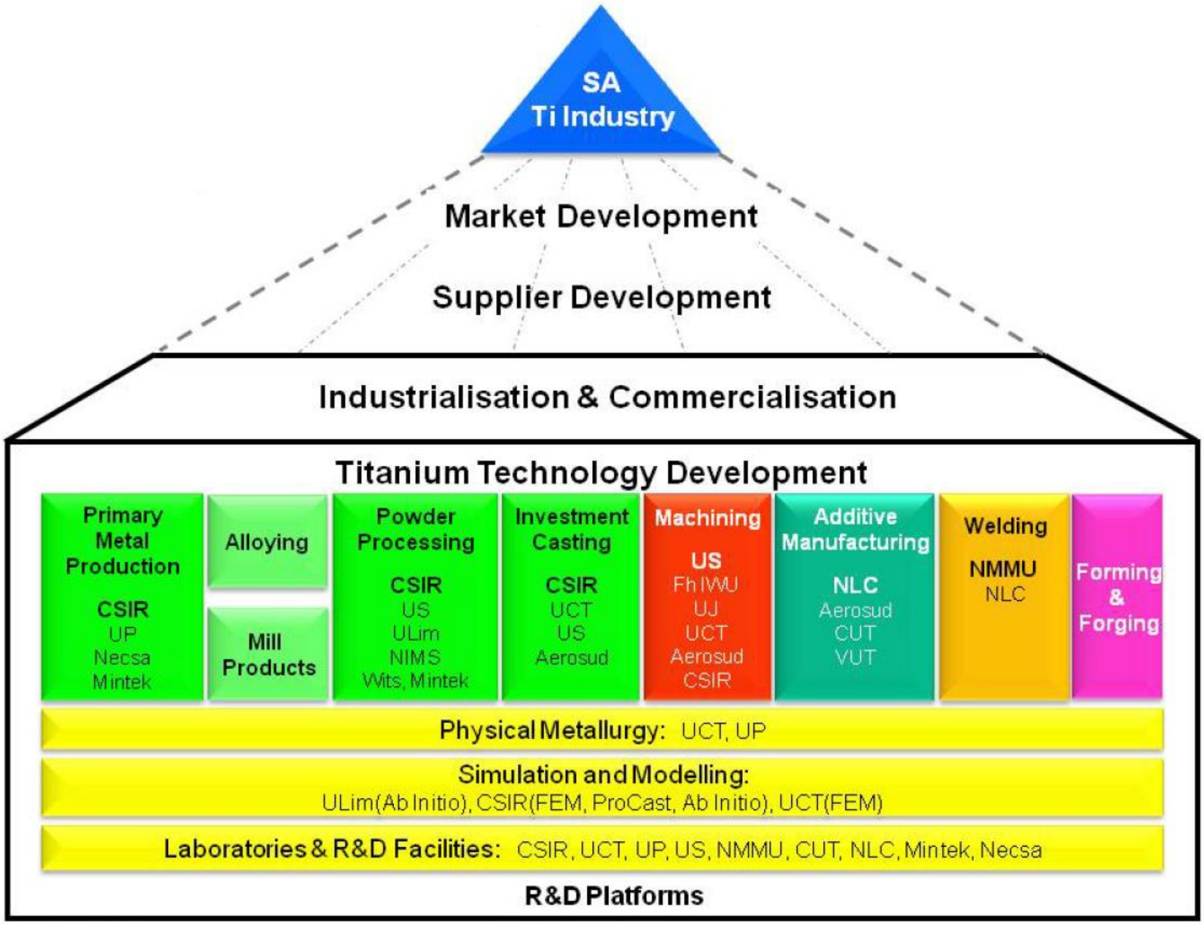

Figure 2: TiCoC model for the development of a titanium industry

Two projects have been the catalyst for the research into the machining of titanium. They are "High Performance Machining of Light Metals with an Emphasis on Titanium and Selected Alloys" (Dimitrov, 2007) as well as "Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications" (Dimitrov & Damm, 2013) which is the more recent of the two. The problem, which this thesis aims to address and contribute to a solution, is that there exist no current strategies which aim to protect the research being conducted into titanium machining and ensure they are implemented into industry successfully. The focus of this particular thesis is therefore on the development of the technology transfer and intellectual property (IP) strategies which are identified in both projects as an important area of research required to ensure the successful implementation of the titanium industry in South Africa. These strategies are not only linked to the protection and transfer of any technologies which might materialise as a result of the projects mentioned. Instead they aim to provide these services to any developments in the field of titanium machining, be it now or in the future.

In order to establish an efficient titanium machining industry in South Africa one needs to consider the importance of IP in new research and development, as well as the importance of a plan for technology transfer. An intellectual property strategy is as important as the development of new technologies. Without consideration for IP, all industry competitiveness could be lost. A technology transfer strategy ensures that new developments in technology are implemented effectively into industry and that the knowledge required to exploit the new technologies reaches the end user. It also provides a means of determining how effective the new technology has been incorporated into industry by providing feedback allowing future transfers to be improved upon.

1.2 Main Objectives

This thesis has two main objectives:

- The first is to develop a technology transfer plan, detailing how the titanium machining technology, tacit knowledge and skills developed will be transferred to and retained by local firms, and how it will impact on their capabilities and competitiveness.
- The second is to develop an IP strategy for titanium machining. This will ensure that the outputs of the research and development work being undertaken is exploited predominantly by the South African industrial partners involved, therefore constituting a competitive market advantage for them.

Furthermore, it is required to map the linkages between the research partners and industrial partners. In order to achieve these goals, this thesis needs to serve as a source of knowledge on the topics of both technology transfer as well as intellectual property. This thesis aims not to provide one course of action in which to transfer technology or protect IP but rather to share knowledge on the topics so that the researchers can make informed decisions which are most relevant to their specific work. During technology transfer, one of the most important factors to consider is how to transfer not only the technology but the intellectual property that goes with that technology. How the technology works and how to use it correctly are vital pieces of information, essential to the technologies successful implementation. So, although there are two separate topics considered in this thesis, they often overlap.

As the development of both the IP and technology transfer strategy are running in parallel with other research for titanium machining, to which they ultimately will apply to, it is important to note that they will not be conventional. What is meant by this is that they are not being developed to protect specific pieces of IP or transfer specific aspects of technology but rather to prepare for these scenarios. Since this is a relatively new area of research for South Africa, which is still being undertaken, there is no IP portfolio. In other words, there is no registered IP, so an IP audit cannot be conducted and a definitive strategy developed for how to market and protect specific aspects of technology. Instead, a broader approach is followed in which options are described so, that once new technology is developed, informed decisions can be made with regards to the IP that comes with it. The same goes for the transfer of technology, however, there have been preliminary tests and implementations conducted at the industrial partners to determine how transferrable such research is as well as to gain an insight into the industrial environment. These tests and implementations are described within the thesis. Due to the shortage of data available qualitative models will be explored in the technology transfer chapter rather than quantitative ones.

An important note to make while reading this thesis is the difference between a strategy, which is presented by this here, and the management of IP and technology. A strategy describes courses of action which management then implements based on the particular situation at hand. Although the word management is used in this thesis, it describes general practices for the management of IP rather than describing actual cases and making research specific decisions for the parties involved in the development of the titanium machining industry. The following points summarise the specific objectives of this thesis:

- Analysis of the technological chain for titanium machining: What this entails is the development of an overview of titanium metal as well as a look at the titanium machining industry and ultimately an analysis of the titanium machining technology chain in order to identify where to focus future research.
- The development of a Technology Transfer strategy: A plan for research input, describing the research avenues outlined by the project “Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications” must be presented. A plan for research outputs which explores the different policies and practical aspects of technology transfer before detailing existing technology transfer methods must researched. The plan must be finalised by the development of a technology transfer model relevant for the titanium machining research being conducted.
- The development of an Intellectual Property strategy: Research into IP basics and potential issues which one might come across while attempting to protect their IP must be conducted. The development of measures for IP localisation and retention must be explored. This includes technology licensing, IP monitoring and enforcement as well as the contractual agreements in place for the titanium machining research initiative. Information on the technology transfer office at Stellenbosch University, InnovUS, should also be detailed. Finally a plan for IP outputs and their possible patentability must be developed.
- Implementation of the technology transfer strategy: A description of the various industrial partners involved in the titanium machining research initiative must be presented. As a method of validation for the technology transfer strategy developed, the technology implementations which have occurred to date as well as the future plans for technology transfer must be presented.
- The documentation and mapping of all parties involved in the research and development of titanium machining competencies according to their involvement. This will make the transfer of technology easier as well as providing an understanding as to who the IP rights will belong to.

1.3 Research Methodology

As mentioned earlier, the development of the IP strategy and technology transfer strategy for this thesis was conducted in parallel to the other research being done for the titanium machining research initiative. As such, an approach was followed which would develop these strategies in such a way as to prepare for future IP outputs and technology transfer implementations. This approach is defined as follows:

- Research into the basics of technology transfer and IP must be conducted. These basics should then be considered in the context of the titanium machining industry whenever possible.
- Further information should be gathered with regards to IP by consulting with InnovUS and making them aware of the titanium machining research being conducted.
- For the development of the technology transfer strategy, visits planned to certain industrial partners should assist in developing a better understanding of their work environment as well as helping to determine where they feel the focus of research should be aimed.

- Ultimately, research as well as interaction with professionals should guide the development of this thesis along with the current situation with regards to the progress of the titanium machining research.
- Validation for the technology transfer strategy will be obtained through tests conducted at certain industrial partners, as well as through the planning of future industrial partner implementations.

No protectable IP has been developed as of yet, as the research which has been done to date has been largely in the form of tests, in order to gain a better understanding into the capabilities of Stellenbosch University researchers and the industrial partners. Even though this is the case for the moment, the IP strategy has been developed in such a way as to guide any researcher to understand whether or not they have some protectable IP, and if so, how they should move forward in order to gain said protection.

Chapter 2. Analysis of the Technological Chains

Before a strategy for the transfer of technology is described, the direction in which the research is being aimed must be explored. In order to do this a technology chain needs to be developed. With the business environment being extremely competitive, both locally and globally, it is important to plan into which technologies research and development is directed. Technology road mapping allows companies to do just this. It identifies critical technologies and technology gaps, providing information on how best to make technology investment decisions and identifying ways to leverage research and development investments (Garcia & Bray, 1997).

In order to develop the technology chains for titanium machining we must first understand titanium itself and why it has become such a popular metal in many industries. Some history, basic properties as well titanium's commercial significance is explored in the beginning of this chapter. The titanium industry, both local as well as global, is then described. Finally, some industry targets are identified followed by the technology chain analysis. From the analysis, the technology goals and barriers for titanium machining are derived.

2.1 Titanium

Titanium is a silver-white refractory metal. The term 'refractory metal' is used to describe a group of metal elements that have exceptionally high melting points and are resistant to wear, corrosion and deformation (Bell, n.d.). Titanium is the ninth most abundant element in the earth's crust and the seventh most abundant metal. Titanium is found in most rocks, sand, clay and other soils. It is also present in plants and animals, natural waters, and meteorites and stars. The two prime commercial minerals in which titanium is found are ilmenite ($FeTiO_3$) and rutile (TiO_2) (Pallardy, 2009). Pure titanium is ductile, about half as dense as iron and less than twice as dense as aluminium; it can be polished to a high lustre. The metal has a very low electrical and thermal conductivity (Pallardy, 2009). The most widely used titanium alloy (6-4 containing 6% aluminium and 4% vanadium) has the highest strength-to-weight ratio of any structural metal. It is some 1.8 times greater than that of aluminium 6061 (with 1.2% silicon and 0.4% magnesium) and 2.9 times that of 316 stainless steel (Roskill, 2013). It is compatible with carbon fibre reinforced polymers (CFRP) and is highly resistant to chemical attack, particularly from salt or polluted waters. On the other hand, it combines with atmospheric gases in solid solution, adding greatly to the cost of melting and alloying (Roskill, 2013).

2.1.1 History

The first titanium mineral, a black sand called menachanite, was discovered in 1791 in Cornwall by the Reverend William Gregor. He analysed it and deduced it was made up of the oxides of iron and an unknown metal, and reported it as such to the Royal Geological Society of Cornwall. In 1795, the German scientist Martin Heinrich Klaproth of Berlin investigated a red ore known as Schörl from Hungary. This is a form of rutile (TiO_2) and Klaproth realised it was the oxide of a previously unknown element which he named titanium after the Titans in Greek mythology. When he was told of Gregor's discovery he investigated menachanite and confirmed it too contained titanium. Pure titanium however, was not produced until 1910. This was achieved by Matthew Albert Hunter who made pure titanium metal by heating titanium tetrachloride and sodium metal (Royal Society of Chemistry, 2011).

2.1.2 Material Properties

Some of the basic properties of titanium, as well as those of aluminium and iron for comparison, are presented in Table 1.

Table 1: Basic properties of titanium, aluminium and iron (Royal Society of Chemistry, 2011)

Name	Titanium	Aluminium	Iron
Symbol	Ti	Al	Fe
Atomic Number	22	13	26
Relative Atomic Mass	47.867	26.982	55.845
Melting Point	1670 °C (1943.15 K)	660 °C (933.47 K)	1538 °C (1811.15 K)
Boiling Point	3287 °C (3560.15 K)	2519 °C (2792.15 K)	2861 °C (3134.15 K)
Density	4508 kg/m^3	2698 kg/m^3	7873 kg/m^3
Element Category	Transitional metal	Post transitional metal	Transitional metal

From this table we can see two of titanium's important qualities, its relatively low density as well as its high melting point. The low density contributes to titanium's exceptional strength to weight ratio which can be seen in the Figure 3, compared to that of both aluminium as well as steel. The values obtained were calculated using the tensile strength data as well as the densities for Titanium Ti-6Al-4V, Aluminium 6061-T6 as well as AISI Type 316 Stainless Steel found on the Aerospace Specification Metals website (Aerospace Specification Metals, 2014).

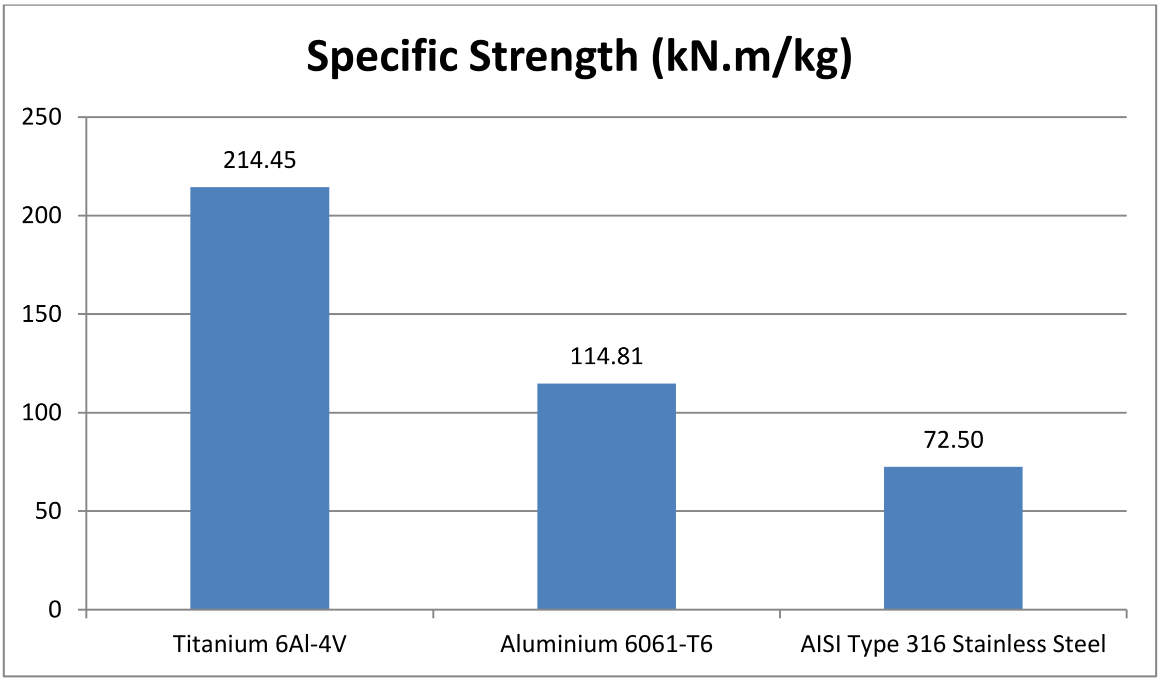

Figure 3: Strength to weight ratio of titanium, aluminium and steel

Titanium's properties have aspects which are both positive and negative when its commercial significance is considered. These are listed in the 2013 Roskill report on titanium metal and are presented below. Many of these aspects describe the reasons that titanium machining can produce high quality end products ideal for aerospace and medical industries. It must be noted that although the list of positive aspects states that titanium is 'machineable despite perceptions that it is difficult to machine', the ability to machine titanium efficiently is dependent on a manufacturers titanium machining knowledge. With proper procedures, titanium can be fabricated using techniques no more difficult than those used for the machining of stainless steel. The difficulties associated with the machining of titanium are discussed later in this chapter in the section on the titanium machining technology chain.

The positive aspects of titanium's properties are:

- Low density (about 56% of stainless steel)
- Highest strength to density ratio of all metals up to 500°C
- Low modulus of elasticity (55% of steel)
- Extremely corrosion resistant in a range of environments including seawater, body fluids and fruit and vegetable juices, and generally superior to stainless steel and copper alloys
- Amenable to processing by powder metal technology
- Non-toxic and compatible with human tissue and bones
- Forgeable using most standard techniques
- Castable, formable and machineable despite perceptions that it is difficult to machine
- Joinable by fusion welding, adhesives, and brazing
- It has a unique ability to be effectively coupled with carbon fibre reinforced polymers (CFRP), mainly because of a similar coefficient of expansion

The negative aspects of titanium's properties are:

- Difficulty of extraction due to the strength of its bond with oxygen
- Corrodes rapidly in concentrated hydrochloric, hydrofluoric and sulphuric acids, hot caustic soda and phosphoric acid, and boiling aluminium chloride
- Corrodes in dry chlorine, ammonia (above 150°C) and hydrogen sulphide (above 150°C)
- Affinity for common gases such as oxygen, nitrogen, carbon dioxide and hydrogen during melting and in interstitial solid solution, which makes melting and alloying processes costly and maintaining purity difficult.

2.1.3 Occurrence and Extraction

The division of titanium minerals produced across the world is represented in Figure 4, in which we can see that South Africa ranks second only to Australia. Richards Bay Minerals, in KwaZulu Natal, is the world's single largest source of contained titanium dioxide, the naturally occurring oxide of titanium, with most production being in slag used for pigments. It produces about 100 kilotons of rutile per annum, some of which is used in titanium sponge production. Another major producer in South Africa is New Tronox which produced 48 kilotons of rutile in 2011 (Roskill, 2013).

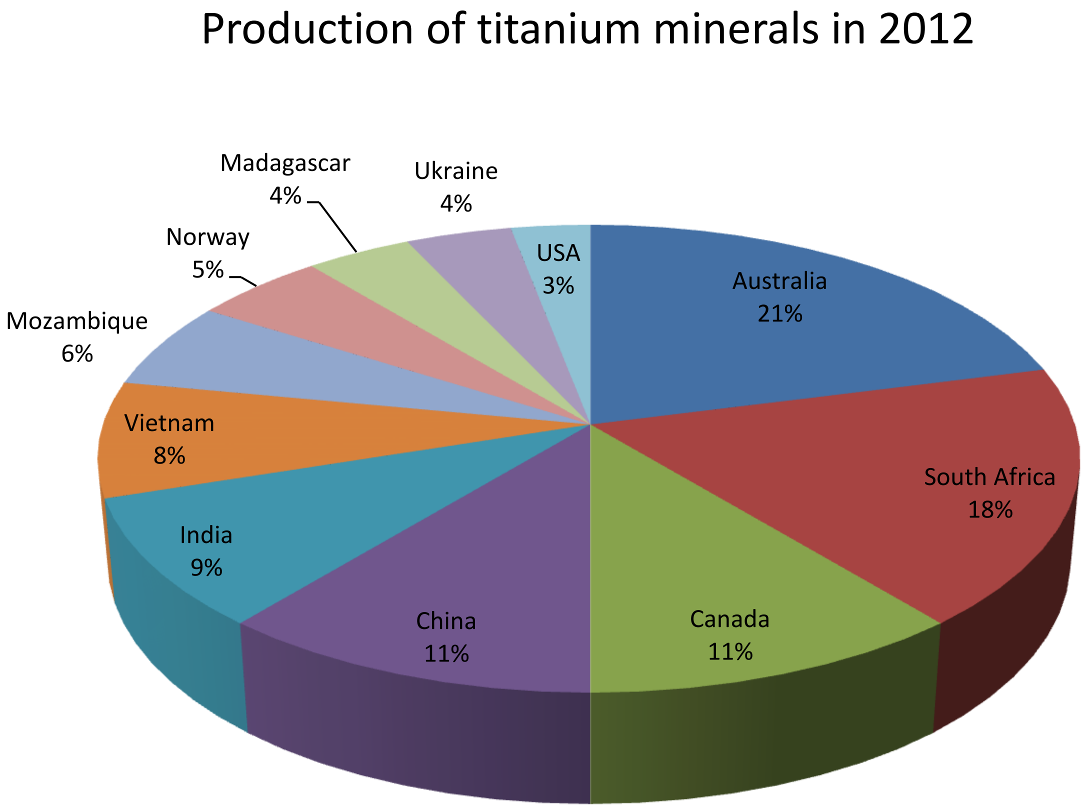

Figure 4: Production of titanium minerals by country (Roskill, 2013)

Titanium is recovered as 'sponge' (so-called because of its appearance) by the Kroll process in which the ore (ilmenite or rutile) is converted to titanium tetrachloride and reduced with magnesium (Roskill, 2013). This process has proven to be a costly method made even more expensive by the fact that it wastes magnesium during the procedure (Van Rensselar, 2012). The original Kroll process, however, has undergone several modifications in the past few decades. Technological breakthroughs in the Kroll process as well as in magnesium recycling have resulted in a significant reduction in the production cost of the metal. Once in sponge form, the titanium may then be fused in an atmosphere of argon or helium in an electric arc and be cast into ingots (Pallardy, 2009).

2.2 Titanium Machining

2.2.1 The Titanium Beneficiation Value Chain

The global market for titanium in mill products was about 165 kilotons in both 2011 and 2012. The markets exist mainly in China, the USA and Europe where they are divided amongst the sectors, aerospace, industrial as well as consumer and other applications. The demand is being forecast to grow by 4.6% per annum up to 2018 which will result in a consumption of 216 kilotons of mill products requiring up to 310 kilotons of sponge (Roskill, 2013).

Although South Africa produces plenty of raw titanium minerals, most of it is converted to slag and exported as a relatively low value commodity. There is potential to expand local industrial capacity and capabilities to include the production of mill products (intermediate products such as plate, sheet and bar) as well as finished products targeted at the industrial, aerospace, and biomedical markets. In order to achieve the goal of producing finished titanium products, one of the key building blocks, and the focus of this research area, the machining of titanium metal must be developed. Once this competency has been developed, it will allow for the production of finished products for the automotive, aerospace and biomedical industries. As South Africa has one of the largest resources of titanium in the world, any local companies which can efficiently machine it will be able to achieve a significant competitive advantage in that the raw materials are readily available.

The Figure 5 provides us with an idea of just how much value can be added to the resource that is titanium. The prices provided in the figure are in US dollars. Titanium's journey to the final product is a fairly lengthy one, however, it can be seen that value is added at every step along the way. Most of the titanium in South Africa is exported as slag as was mentioned earlier. This slag sells for around 79 US cents per kilogram, in the South African rand this equates to around R9 per kilogram. With the necessary competencies allowing for the production of final titanium components this number could reach from anywhere between R1700 to R220000 depending on the type of component produced.

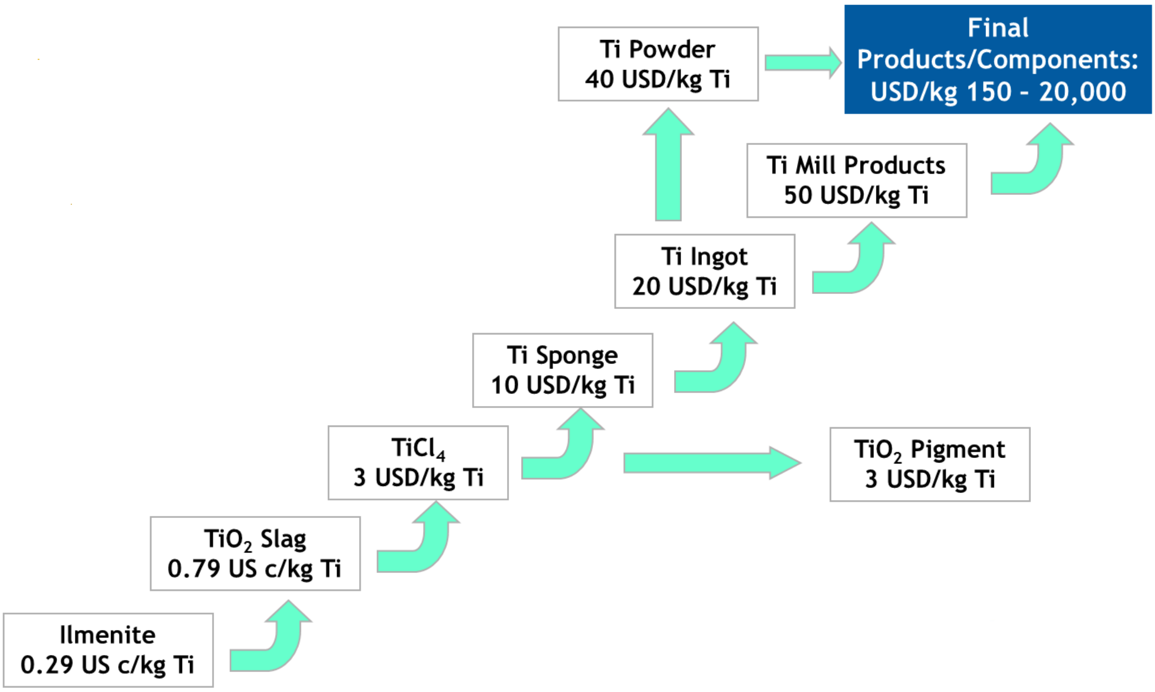

Figure 5: Titanium value chain (Damm, 2012)

2.2.2 Industry Targets

Before we consider the technology gaps associated with the machining of titanium, let us first understand why titanium machining could be beneficial to the industries of South Africa as well as what factors these industries consider. A large number of industries and applications are covered by titanium machining such as oil and gas, marine, aerospace, medical, chemical and automotive. These industries will be the driving force behind the research and investment that will help titanium machining technology reach new heights. Figure 6, shows the worlds estimated consumption of titanium mill products by major sector for 2012. The percentages are that of 165 kilotons total consumption for the year. It is important to note that the consumer, medical and other sectors include non-aerospace military applications.

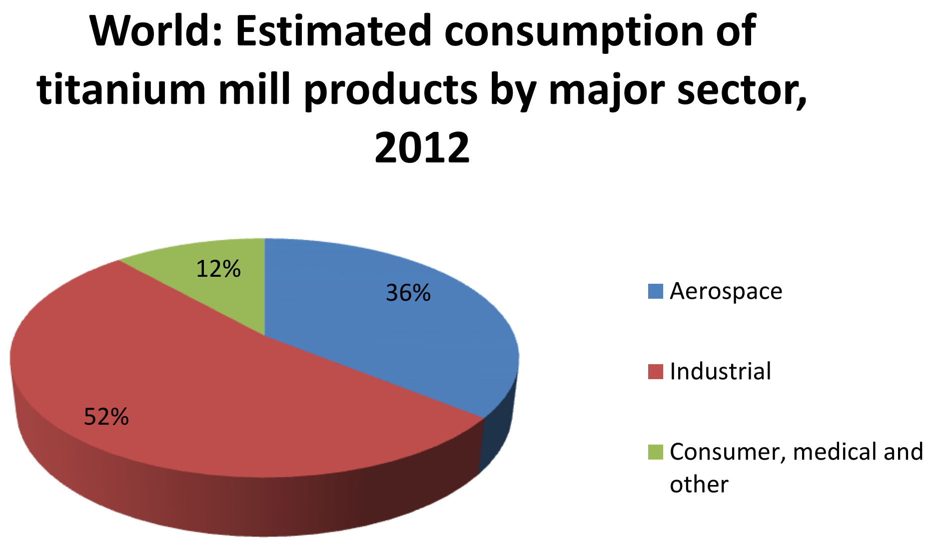

Figure 6: Consumption of titanium mill products by major sectors (Roskill, 2013)

Costs are a major driving factor when it comes to industry and the implementation of new technologies. Companies are usually very interested in the return on their investment, which we have already seen to have the potential to be rather large when the titanium value chain is consulted. However, the risk perceived, as well as the returns expected, may vary significantly across different industries and should therefore be considered individually. When it comes to the aerospace industry, with which this research initiative is closely linked, the justifications for the use of titanium include (Boyer, 1994) :

- Weight savings: These weight savings are due to the high strength to weight ratio of titanium. Titanium is less dense than steel and therefore the same part is around 45% lighter when made from titanium.
- Operating temperature: Titanium parts can replace aluminium parts in environments where the operating temperature exceeds 130C, the normal maximum operating temperature for aluminium.
- Corrosion resistance: Titanium is highly corrosion resistant and does not require corrosion resistant coatings or paints.
- Composite compatibility: Polymer matrix composite compatibility is becoming an issue with the increased use of composite structures on aircraft. Titanium is galvanically compatible with the carbon fibre in the composites, unlike aluminium and low alloy steels which generate a significant galvanic potential.

These advantages need to be weighed against the higher cost of titanium relative to aluminium alloys and steels. It is the purpose of research initiatives such as this to close this gap in costs by developing the most efficient ways in which to machine titanium.

2.2.3 Technology Chain Analysis

The machining technology chain was developed and visualised. It can be found in Appendix 1. The technology chain was used to identify any major technology gaps which could then be considered as research opportunities. Together with Aerosud, an industrial partner in the research, three major shortcomings were realised and answer the question: What changes need to be made in order for Aerosud to start machining titanium today? The three shortcomings are listed and described briefly below. Although going into detail on each of these is beyond the scope of this report, it is important to take note of them as they represent research issues, which are required in order to achieve the "technology goals" and to "push barriers" (Dimitrov, 2013).

- Tool selection: Tool wear is greatly increased when machining titanium. Research opportunities should consider new tool materials and tool wear.
- Cooling technologies: Cooling becomes a problem when machining titanium as it is a poor conductor of heat. Research into alternative cooling technologies and techniques needs to be considered. Aerosud currently employs flood cooling which would not provide sufficient cooling for the machining of titanium.
- Cutting strategies: The programming of tool paths is dependent on the material being machined and its respective material properties. Research opportunities should consider how titanium behaves while being machined and how best to program tool paths using this knowledge. Although Aerosud has programmers skilled in the tool path programming for the machining of aluminium, they have not had experience with the machining of titanium.

The titanium project entitled "Resource efficient process chains for titanium components in aerospace, automotive, and medical applications" notes the challenges faced when considering the machining of titanium. It states that, "In spite of low cutting speeds high tool wear occurs due to poor machinability, limiting the achievable material removal rate. Development of cutting materials/tools, cooling lubricant strategy and machining strategies is mandatory for roughing and finishing. The desired reduction in the machining time per component is the basis for improving resource efficiency in cutting. This results in a substantial reduction of the auxiliary materials used and electric energy per machined component." It is clear that the focus for further research is on these issues to ensure the development of efficient titanium machining in South Africa.

2.2.4 Technology Goals and Barriers

In order to reach the goal of a reliable, predictable and affordable titanium machining industry, we need to determine what research is required to overcome the barriers which stand in our way. The envisaged targets for the improvement of titanium machining as can be found in the project "Resource efficient process chains for titanium components in aerospace, automotive, and medical applications" include:

- Reduction in machining time (up to 20%)
- Reduction in material wastage by exploring the use of preform technologies such as powder metallurgy (reduce wastage by 50%);
- Definition and modelling (cost, time) of alternative and more efficient manufacturing process chains for selected demonstrator components.

Although the technology to machine titanium in South Africa is available, it needs to be refined from an industrial point of view. Certain industrial partners are very efficient in their ability to machine aluminium parts using a digital manufacturing process and a similar level of efficiency needs to be ensured for a titanium machining process. The way to do this is to look at the following aspects with regards to the machining of titanium:

- Machine time reduction
- Cost optimisation
- Resource efficiency

The reduction of machine time is achieved through optimal tool path programming together with a level of confidence that once the mill product enters the machine, the selected tools and cooling methods will be able to handle the job which is required of them. Again we can reference the digital manufacturing process which is employed for the machining of aluminium. This incorporates tool path programming, tool selection and knowledge of each machines capability.

Cost optimisation is achieved with techno-economic planning, as well as standards on the machining room floor. Cost optimisation should come through the optimisation of process chains, identification of potential savings (such as resource efficiency) and the assessment of the impact of titanium machining on the capabilities and competitiveness of industrial partners. These topics are dealt with in a techno-economic study on titanium machining, which forms part of the titanium machining research.

Developing and adopting standards is also an important consideration to take into account when introducing the titanium machining strategy into South Africa. Product and material certifications that conform to internationally recognised standards will promote the adoption of titanium machining.

2.3 Summary

With the abundance of titanium available to South Africa as well as the potential to add huge value to such a resource, the development of a means to produce titanium components is already justified. However, much research and development will be required in order to machine titanium on a competitive level.

The first step in the identification of the technology gaps which need to be bridged is an understanding of the metal itself. Some of the key properties which make titanium such a desirable metal to use are recapped below:

- A high specific strength or strength to weight ratio. This property is especially important to the aerospace industry where weight saving while maintaining strength is essential.
- Corrosion resistance.
- A high operating temperature.
- Composite compatibility. Another property which is particularly important to the aerospace industry as metals are often used alongside carbon fibre composites.
- Compatible with human tissue and bone.

Although titanium has many beneficial properties it cannot be machined in the same way in which aluminium or steel is currently being. In order to machine titanium efficiently the following aspects need to be looked at:

- Machine time reduction
- Cost optimisation
- Resource efficiency

These aspects can be improved through the bridging of the technology gaps which exist, namely:

- Tool selection
- Cooling technologies
- Cutting strategies

as well as through effective techno economic analysis, which although is not expanded upon in this report, is being researched for titanium machining. The following chapter will detail exactly how these technology gaps intend to be bridged.

Chapter 3. Technology Transfer Strategy

In this chapter, plans are detailed for both the input of new research avenues as well as the output of research which emanates from the industrial strategy. The plan for research input follows the previous chapter, which identified critical technologies and technology gaps. This is achieved by providing details as to how exactly these gaps intend to be bridged. Research output is slightly more complicated as it essentially explains a means to transfer technology developed through research to industry. The plan for the output of research is handled through the development of a technology transfer model. However, before a model unique to this situation can be developed, some existing policies and models are explored in order to provide some insight as to what has been done before. Validation for this chapter is achieved by describing technology transfer which has occurred to date as well as by detailing a plan for future technology transfer. This validation is found in Chapter 5.

3.1 A Plan for Research Input

As mentioned earlier the titanium machining project entitled “Resource efficient process chains for titanium components in aerospace, automotive, and medical applications” is where the focus for development now lies. The proposal describes three new work packages which will be the focus of research and development going forward. These work packages (WP) are listed below (Dimitrov & Damm, 2013):

- WP1: Competence integration, demonstration and validation of alternate process chains
- WP2: Further development of current research avenues
- WP3: Technology transfer and commercialisation

The first work package describes five processes/process combinations, each with a demonstrator part which will also be used for validation purposes. They are listed below along with their respective demonstrator parts.

- Process combination “Forming – Machining” (Banana brace)
- Process combination “Press and sinter – Machining” (Supporting bracket)
- Process combination “Additive manufacturing – Machining” (Fitting)
- Machining (Intercostal)
- Dental implant (Titanium dental implant)

It is in the second of these work packages, the further development of current research avenues, which focuses on many of the shortcoming which have been identified by examining the titanium machining technology chain as well as meeting with the experts on machining. A complete industrial partner/research institute linkage map for the topics listed in these work packages can be found in Appendix 2, showing which universities will be involved with the different topics as well as which industrial partners they will be performed in collaboration with (where applicable).

1. High Performance machining:

- Surface integrity and residual stresses:
  - Study of physical and material characteristics of alpha case

  - Study of new alpha case detection methods (X-ray diffraction, Neutron diffraction, synchrotron diffraction and correlation with industrial methods)
  - Study of fracture behaviour of alpha case
  - Synthesis of quality control methodology for alpha case removal
- Alpha-case removal:
  - Study of physical and material characteristics of alpha case
  - Study of new alpha case detection methods (X-ray diffraction, Neutron diffraction, synchrotron diffraction and correlation with industrial methods)
  - Study of fracture behaviour of alpha case
  - Synthesis of quality control methodology for alpha case removal
- Advanced cooling strategies and lubrication:
  - Evaluation and customisation of cooling and lubrication techniques for SA use – a systematic review of past results, as well as data collection and analysis of current studies.
  - Investigation of the impact of different coolants on titanium machining depending on different cutting parameters. Of particular importance are studies on the fatigue life of Ti components if machining is done at higher speeds leading to elevated work piece temperatures.
- Cutting strategies evaluation and selection:
  - Several cutting strategies still need to be tested on different geometric features to determine which strategy gives the best results with which feature. To do this, simulations will be run, on which base a strategy selection procedure can be developed.
  - The constant engagement strategy gave very good results for machining titanium. The reason for that should be seen in the moderate forces that are exerted on the cutting tool. This however still needs to be tested. Using a Kistler Piezo-Dynamometer the forces will be measured while implementing a constant engagement strategy and the data will be used to evaluate the effect of the cutting force on tool life.
  - Analysis and evaluation of available CAD/CAM software with regards to efficiency and user-friendliness of available machining strategies.

2. Metallurgical Aspects and Near-Net Shape Forming Technologies:

- Development of demonstrator preforms via cast billet and powder sintering route
  - Design tooling for powder compaction
  - Design tooling for forging operation
  - Adapt existing furnace (or develop new furnace) for hydrogenation treatment
  - Produce billets via two process routes, subject to hydrogenation as necessary
  - Investigate billet integrity
  - Conduct forging trials
  - Assess microstructure and mechanical property integrity
  - Machinability studies
- Further development of sintered titanium processes
  - Press and sinter of bimodal mixtures
  - Powder injection moulding

3. Modelling and simulation

- Cost modelling for titanium machining
- Development of a technology roadmap and IP strategy for titanium machining
- Techno-economic modelling of titanium machining

The third work package focuses on the following aspects of technology transfer and commercialisation:

- Machine performance mapping and calibration methodology
- Skills development and results dissemination program
- Identification and evaluation of market potential for technology commercialisation

With respect to the second work package, it can be seen that the direction of the research and development being done is in the right direction as far as the machining of technology is concerned. Identifying the critical technology gaps and focusing resources into bridging them is the fastest way to achieve the goals of the industrial strategy. For the purposes of validation, focus will be shifted to the first work package, using the five processes/process combinations along with their demonstrator parts to develop a means of technology transfer suitable to each of them.

3.2 A Plan for Research Output

The plan for research output is essentially a technology transfer strategy. Technology transfer is the process by which knowledge or technology developed in one place is transferred and applied in another place. Technology is usually transferred from an institute which conducts research and development, to industry where the new innovations are applied to improve the relevant industry. In order to achieve successful technology transfer, there are certain resources which need to be in place, as well as certain aspects of the technology development which have to be conducted. Intellectual property rights (IPR's) are an important place to start, as any technology which we wish to transfer, must first be protected. The IP strategy which is described in this thesis is intended to guide one to successfully achieve an understanding of how IP can be protected and managed. One also needs to implement ways in which to test new technology and verify its usefulness. This is something which is being done at the Stellenbosch University for titanium machining. It is important that one possesses the right resources for this step in the development of new technology, such as machines, tools and know-how. Once a new technology is protected and has been tested, industrial partnerships along with licensing agreements can take the technology to the market where it can be exploited. The industrial partners, once they have received the technologies, will have to implement them into their business plans to ensure that the technologies are used to expand their capabilities and maximise their profits. It is important to keep in mind the costs that accompany technology development and transfer. These include IPR registration and annual fees, as well as costs associated with the development and implementation of the technology. The titanium machining research initiative is government funded, as has been previously mentioned and costs associated with the registration of IP will be the responsibility of the technology transfer office at the Stellenbosch University, InnovUS.

The long term goals of technology transfer are to sustain economic growth through the development and commercialisation of new technologies (Loise, 2011). In order to achieve this we need to consider some key aspects listed below:

- A dedicated technology transfer and support team. InnovUS will assist in the transfer of technology and further support can be found by the department of science and technology (DST) who have contracted this research.
- Understanding the marketplace and the local regional economy. The titanium machining industry in South Africa is still at an early stage of development, by implementing it slowly much can be learned as to how it will function in this country. Industrial partners will have the know-how when it comes to the machining industry, and this makes them the ideal candidates to expand into the machining of titanium.
- Establishing university-private sector relationships that may include additional funding. If this research can successfully achieve its goals, further research into the field of titanium machining can be conducted, benefitting both the universities as well as the industry in South Africa.
- Bridging the gap between invention and commercialisation. This is one of the main aims of a technology transfer strategy. How do we take our newly developed research and implement in successfully into the industry in question?
- Outstanding researchers doing outstanding research. Some of the top universities in the country are working on this research initiative with input from the government's research and development department and some of the leading industrial partners in the machining industry.
- Long term financial commitment. The department of science and technology is providing the funding for this industrial strategy and contractual agreements are in place.

In this plan for research output we begin by exploring existing literature on the topic of technology transfer before developing a means to transfer the technologies being researched. Ultimately a technology transfer model is developed and validated through tests and implementations at certain industrial partners as well as through a plan of action to transfer the research in the first work package.

3.2.1 Policies and Practical Aspects for University-Industry Technology Transfer

There are certain policies and practical aspects which need to be implemented on both a national and institutional levels in order for successful technology transfer between universities and industry. In this section some of these are considered with a focus on creating an effective structure for the management of IP rights by universities and their transfer to industry. These policies are described in the WIPO publication technology transfer, intellectual property and effective university-industry partnerships (WIPO, 2007).

An efficient IP system and a clear and transparent policy on ownership of IP are two very important tools which facilitate the transfer of technology from universities to the industry. An efficient IP system uses IP rights to protect new technology with an IP office to examine, register and grant said rights. The availability of qualified IP professionals who can assist universities throughout the patent life cycle, including the application process, the negotiation of licenses over patented technology and the settlement of disputes over IP rights are also key components in this system. Ownership of the rights by the universities provides a clear and predictable way for stakeholders to attain the technology and also facilitates joint research between different organisations. Other reasons for the ownership being assigned to universities include (WIPO, 2007):

- It facilitates a professional technology transfer strategy.

- It enables researchers to focus on their core research skills without having to worry about ownership issues.
- It creates an incentive for the university to support and promote the transfer of technology.
- Costs of patenting can be high for an individual researcher to fund.
- A research project with many researchers can create fragmentation of ownership and thereby complicate transfer and commercialisation. Ownership by the university negates this issue.
- It generates additional income for the university.

Internal policies on IP at universities are also important and help build relationships with the private sector. Some of the main objectives of internal policies should be to (WIPO, 2007):

- Provide rules and guidelines for the commercial exploitation of IP generated within the university.
- Ensure that discoveries, inventions and creations generated by staff and students are utilized in ways most likely to benefit the public.
- Establish ownership criteria.
- Define the responsibilities, rights and obligations of all stakeholders.
- Develop basic guidelines for the administration of the IP Policy.
- Define rules for revenue sharing if the commercialization of IP generates income.

Safeguarding public interest is one of the main policies required to facilitate the transfer of technology to industry in order to ensure it is commercialised for the benefit of the public interest. The goal of the titanium industry strategy, being publicly funded, is to do exactly this. Encouraging licensing to local industry ensures that the local economy benefits from newly developed technologies. Another policy is that of the development of skilled human resources. By managing technology transfer activities from universities to the industry many different skilled human resources are required, including legal, business, scientific and licensing expertise. Lack of these human resources can severely affect technology transfer operations. It is therefore essential to promote training programs to ensure the development of the necessary skills required.

On a more practical level, technology transfer offices need to be established, such as InnovUS. The advantage of having an office that is specialized in technology transfer is that it enables universities to professionalize their technology transfer activities. Technology transfer offices can provide assistance with regards to patenting decisions and costs as well as the development of procedures for the disclosure of inventions. Researchers in a field such as titanium machining often do not possess the legal knowledge required to protect any IP which they develop. The presence of a technology transfer office ensures that researchers can focus on their work without having to worry about obtaining IP protection unassisted.

3.2.2 Technology Transfer Methods

In this section we begin by considering the different levels on which knowledge and technology can be transferred. Technology transfer is a very complex process and these levels help to simplify it by describing how technology transfer can occur at different stages of research as well as by various different methods. The four levels also provide a means to describe at what stages of knowledge and technology transfer the research into titanium machining has operated to date. The next section in this chapter focuses on existing technology transfer models, particularly the model proposed by

Bozeman, where emphasis is on technology transfer from universities and government laboratories to industry as is the case with the titanium machining research in South Africa. Finally, we consider the technology transfer which has occurred for the titanium machining research initiative and a method for the future is suggested after considering what has been discussed.

3.2.2.1 Knowledge and Technology Transfer Levels

To develop a technology transfer strategy for titanium machining, the levels on which technology transfer is likely to take place must be considered. Figure 7 shows four levels of knowledge and technology transfer, and is based on the technology transfer model suggested by Gibson and Smilor. What each level entails is described in this section as well as on which levels the titanium machining research has achieved successful technology transfer.

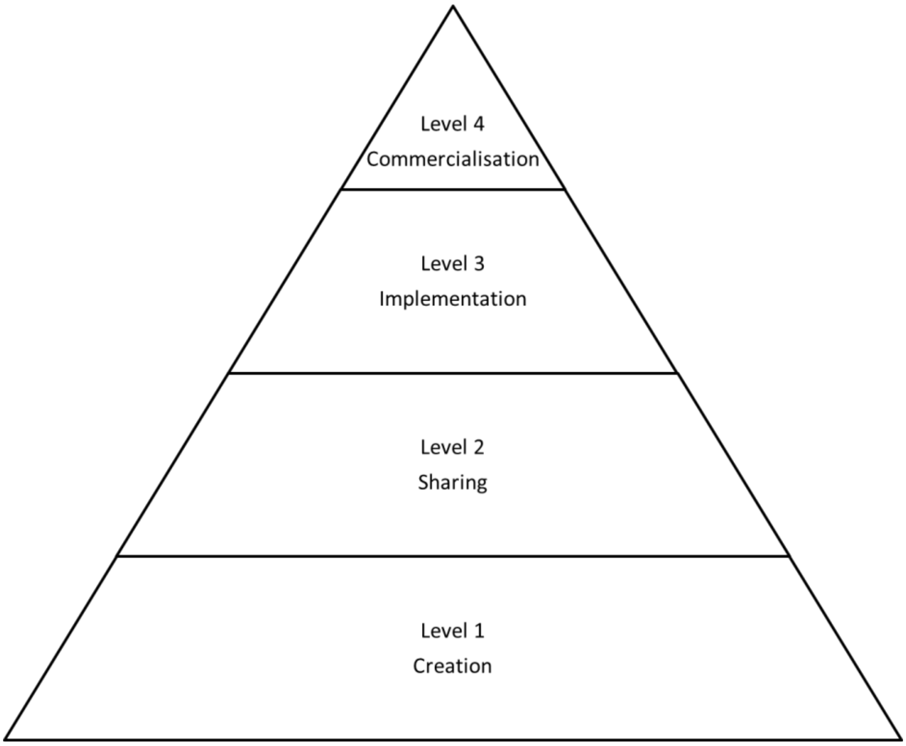

Figure 7: Four levels of knowledge and technology transfer (Gibson & Smilor, 1991)

The first level is where knowledge and technology is created. This is achieved by individuals conducting state of the art research and the transfer of technology is achieved via the announcement of the research results. This can occur by varied means such as research publications, videotapes, teleconferences, news, and anecdotes. At this level, the transfer of technology is a largely passive process as there is little collaboration amongst the researchers and those who take an interest in the knowledge and technology which has been created. Researchers may, however, work in teams or across organizational or even national boundaries in developing the knowledge and technology (Gibson & Sung, 2000). The research into titanium machining has already produced knowledge and technology which has been transferred on this level. Research reports on topics such as the implementation and evaluation of advanced cooling techniques, linking tool wear and surface integrity, approach for cutting strategies evaluation and selection, as well as the implementation and transfer of selected machining strategies, have been presented and, in doing so, transferred on the first level of knowledge and technology transfer.

The second level of knowledge and technology transfer calls for the designated users to become involved. Success on this level requires the knowledge and technology developed to be transferred across personal, functional, or organizational boundaries, and must be accepted and understood by the designated users (Gibson & Sung, 2000). The designated users in the case of the titanium machining industrial strategy are, of course, the industrial partners who will ultimately be the ones who will machine titanium parts. Input from their side is already evident in the research efforts, and collaboration has been achieved via multiple meetings as well as conferences both at Stellenbosch University and at the CSIR in Pretoria. Technology transfer on this level is relatively easy in the case of this undertaking as the industrial partners are experts in the field of machining and understand the difficulties associated with the machining of titanium.

The third level requires the efficient implementation of the knowledge and technology developed. In order for this to occur, the technology users must have the necessary resources required. Knowledge and technology implementation can occur within the user's organization in terms of manufacturing or other processes, or it can occur in terms of services or best practices (Gibson & Sung, 2000). Technology transfer on this level has already been touched upon for titanium machining as tests have been conducted at certain industrial partners in pilot implementations which are described in Chapter 5, technology transfer implementation. Pilot implementations such as these not only provide insight into how easily the research will translate into industry but also provide valuable feedback to the researchers at Stellenbosch University, as well as the other universities involved, as to the environment in which the industrial partners work.

The fourth and final level is one on which the titanium machining research has not yet transferred any knowledge or technology. It is, however, the ultimate goal of the industrial strategy. In order to implement the titanium industry strategy successfully in South Africa, commercialisation of the knowledge and technology needs to be achieved. This level builds cumulatively on the successes achieved in the three previous levels; however, market strength is required. Success on this level is ultimately measured in terms of return of investment or market share for individual entities. As for the research into titanium machining, successful knowledge and technology transfer will be achieved if the research outputs result in a successful titanium machining industry in South Africa.

3.2.2.2 Existing Technology Transfer Models with a Focus on the Bozeman Model

Managers of technology transfer projects face many difficulties and complexities, and over the years many different models of technology transfer have been developed to try and make the process easier and more efficient. There are two types of models that one will generally find, the first, being quantitative, which aims to quantifying parameters of significance in technology transfer. These parameters are then analysed with the aim being to minimise the goal incompatibility between the transferor and transferee of technology. Qualitative models, which are the second kind and also the one upon which this chapter will focus, aim to describe the activities involved in managing the transfer of technology and to deduce both the positive factors and negative issues that can influence the success and effectiveness of technology transfer.

One of the first models considered is the Behrman and Wallender model which has its focus on international technology transfer. Although this model is more relevant to multinational corporations, the research being conducted into titanium machining in South Africa does have the international Fraunhofer aspect to consider. This model proposes a seven stage process for international technology transfer (Behrman & Wallender, 1976):

1. Manufacturing proposal and planning should arrive at decisions regarding location and prepare a business case including good resource assessments.
2. Deciding the product design technologies to be transferred.
3. Specifying details of the plant to be designed to produce the product and other aspects related to construction and infrastructure development.
4. Plant construction and production start-up.
5. Adapting the process and product if needed and strengthening production systems to suit local conditions.
6. Improving the product technology transferred using local skills.
7. Providing external support to strengthen the relationship between the transferor and transferee.

This model has a major weakness, in that during the first three stages, the transferor develops the technology transfer project with minimal involvement of the transferee. The fifth and sixth stages do allow the transferee to assimilate and improve both product and process technology, but by this stage major changes might have been required. Two lessons can be learned from this model. The first lesson is that the transferee needs to be involved right from the beginning in the planning and implementation of a technology transfer project. The second lesson is that a technology transfer project does not end with commencement of production. Time and resources need to be devoted to the improvement of the transferred technology using local skills and with the local conditions in mind.

The next model considered is the Schlie, Radnor and Wad model. This is a simple model in which seven elements of technology transfer are outlined. These seven elements can influence the planning, implementation and eventual success of any technology transfer project (Ramanathan, 2009). These seven elements are:

1. The transferor. The entity selling (or simply transferring) the technology to the recipient.
2. The transferee. The entity buying (or receiving) the technology.
3. The technology that is being transferred.
4. The transfer mechanism. How the technology will be transferred.
5. The transferor environment. The immediate set of conditions in which the transferor is operating. Attributes of this environment which could influence the effectiveness of the technology transfer include economic status, business orientation, stability, attitude and commitment to the transfer project, and operating policies.
6. The transferee environment. The immediate set of conditions in which the transferee is operating. Attributes of this environment which could influence the ability of the transferee to absorb the new technology include physical and organisational infrastructure, skills availability, technological status, business orientation, economic status, attitude and commitment to the transfer project, and stability.
7. The greater environment that surrounds both the transferor and transferee. This can include national as well as global layers. Even though the immediate operating environments of both the transferor and transferee might be favourable to technology transfer, if the greater

environment is not supportive, then the technology transfer could be adversely affected. Factors in the greater environment include; political relationships between countries, exchange rates, investment climates, trade negotiations, balance of trade, relative technological levels, and the status of intellectual property protection regimes. These factors could have a great influence on the success of a technology transfer project, and should be investigated as such.

These seven elements will always exist in technology transfer even though technology and the environments in which it is transferred can change with time. It is this change, the change in the global business setting of today, which makes it important for technology transfer managers to consider these seven elements when planning and implementing a technology transfer project. A weakness of this model is that it offers the transferee no guidelines as to what they should do. What the model does aim to achieve, is to ensure that the choice of technology transfer mechanism be based on a sophisticated understanding of the other six elements.

Finally, let us consider the Bozeman model. This model has been chosen as the main focus of this chapter due to its relevance to the titanium machining research being conducted. The emphasis of the Bozeman model is on technology transfer from universities and government laboratories to industry. Bozeman developed his “contingent effectiveness model of technology transfer” which identifies “five broad dimensions” of the technology transfer process, provides relations amongst these dimensions as well as identifying six “effectiveness criteria”. These effectiveness criteria assess the impact which the technology transfer process has had once the technology has been implemented in to industry. The model is represented graphically in Figure 8 as presented by Bozeman (Bozeman, 2000).

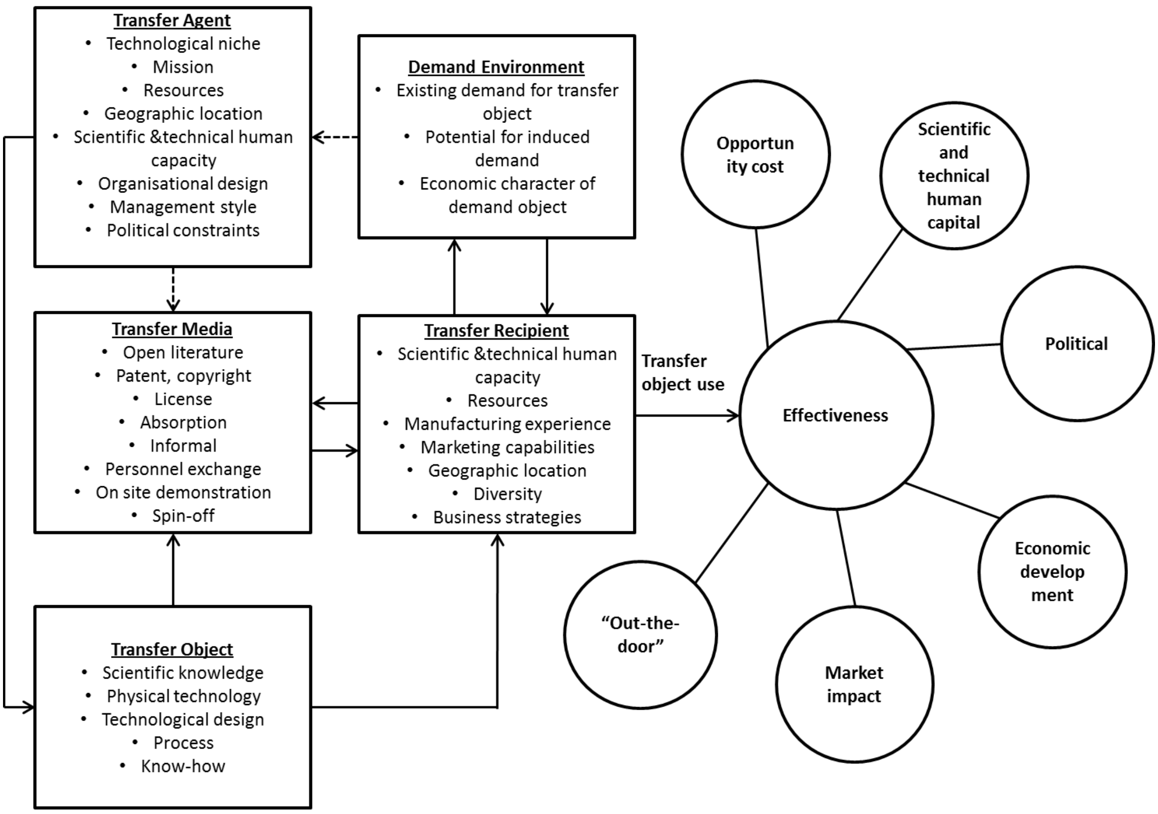

Figure 8: Bozeman's model of technology transfer (Bozeman, 2000)

The arrows in the model indicate relations among the dimensions with the broken lines indicating weaker links. The five dimensions of the model are described in Table 2, along with some examples as presented by Bozeman in his article (Bozeman, 2000).

Table 2: Dimensions of the contingent effectiveness model (Bozeman, 2000)

Dimension	Focus	Examples
Transfer agent	The institution or organisation seeking to transfer the technology.	Government agency, university, private firm. Characteristics of the setting, its culture, organisation and personnel.
Transfer medium	The vehicle, formal or informal, by which the technology is transferred.	License, copyright, Cooperative research and development agreement (CRADA), person-to-person, formal literature.
Transfer object	The content and form of what is transferred, the transfer entity.	Scientific knowledge, technological device, process, know-how and the specific characteristics of each.
Transfer recipient	The organisation or institution receiving the transfer object.	Firm, agency, organisation, consumer, informal group, institution and their associated characteristics.
Demand environment	Factors (market and non-market) pertaining to the need for the transferred object.	Price for technology, substitutability, relation to current technologies and subsidy.

Next, the effectiveness criteria associated with the model are briefly explained in Table 3. It is a major assumption of the contingent effectiveness model that no single notion of effectiveness makes much sense, either theoretically or practically.

It can be seen that the five dimensions of the Bozeman model are similar to the elements of technology transfer proposed by Schlie, Radnor and Wad, however, the Bozeman model provides us with some clues as to how one should assess the success of the technology transfer. They provide us with a means to measure results applicability, in other words, has the technology which has been transferred been successfully implemented and is it performing as it should?

Table 3: Technology transfer effectiveness criteria (Bozeman, 2000)

Effectiveness criterion	Focus	Relation to research and practice
"Out-the-door"	Based on the fact that one organisation has received the technology provided by another, no consideration of its impact.	Extremely common in practice, uncommon as an evaluation measure (except in studies measuring the degree of participation in technology transfer).
Market impact	Has the transfer resulted in a commercial impact, a product, profit or market share change?	Pervasive in both practice and research.
Economic development	Similar to market impact but gauges effects on a regional or national economy rather than a single firm or industry.	Pervasive in both practice and research.
Political reward	Based on the expectation of political reward (e.g. increased funding) flowing from participation in technology transfer.	Pervasive in practice, rarely examined in research.
Opportunity costs	Examines not only alternative uses of resources but also possible impacts on other (than technology transfer) missions of the transfer agent or recipient.	A concern among practitioners, rarely examined in research (except in formal benefit-cost studies).
Scientific and technical human capital	Considers the impacts of technology transfer on the enhanced scientific and technical skills, technically-relevant social capital, and infrastructures (e.g. networks, user groups) supporting scientific and technical work.	A concern among practitioners, rarely examined in research.

3.2.2.3 Translation into the South African Titanium Machining Research

The Bozeman model has many of the elements which titanium machining technology transfer in South Africa would benefit from. Let us first consider the dimensions of the contingent effectiveness model and how these would translate with respect to the research being conducted into titanium machining. Two of these dimensions can be seen to be set in stone for this particular research initiative. The first of these would be the transfer agent, which is Stellenbosch University. The second being the transfer recipient, which will be one of the three industrial partners with whom the research is being developed in partnership with.

The transfer medium will depend on what exactly it is which needs to be transferred, which of course would be the transfer object. This might be a newly developed technology, a process or some essential know-how. A different choice of transfer medium will need to be considered for each unique case. An excellent place to start would be through the introduction of further pilot implementations. As we have already seen, these can be quite successful in not only demonstrating the ability to transfer the research to industry but also by providing valuable feedback for further study. Another reason which makes pilot implementations a good initial medium for transfer is that it allows the researchers to visit the industrial partners on site, giving them an opportunity to experience conditions there as well as ask the professionals who do the work questions related to the research being done. An opinion from the people working in industry can be extremely valuable to a researcher. This could provide them with a completely different perspective on the research which they are conducting.

As far as the demand environment is concerned the titanium industry can be considered as a whole. In the previous chapter it was stated that the demand is being forecast at a growth rate of 4.6% per annum up to the year 2018, resulting in a consumption of 216 kilotons of titanium mill products. Together with the advantages of titanium, which include weight savings, a high operating temperature, corrosion resistance and a composite compatibility, amongst others, the demand environment is a very promising one.

The effectiveness criteria for the contingent effectiveness model which are most appropriate to the titanium machining research are those of market impact as well as economic development which measure the ultimate goal of the industrial strategy. This is the successful introduction of titanium machining into the South African industry allowing for the production of final titanium components. This will greatly increase the value which is added to the large amount of titanium minerals already being produced. The "Out-the door" criteria could also be considered a relevant measure of effectiveness, by confirming that the technology developed actually reaches the industrial partners. There are however, more informative substitutes for this criterion that could be used. For example, does the technology being developed produce the same results at the industrial partners as it does in the research environment? This is a criterion which could be especially useful to assess during a pilot implementation.

3.2.3 Technology Transfer for Titanium Machining Outputs

A final technology transfer model has been developed and is presented in Figure 9. This model is based upon the three models which have been discussed in this chapter, drawing upon the most relevant aspects of each for this titanium machining research initiative.

The six elements of this technology transfer model include the transferor, transferee, technology, transfer mechanism as well as the environments of both the transferor and transferee. The blue line joining the transferor and transferee represents the need for communication throughout the development of the research from project proposals and planning all the way through to commercialisation. The red line represents the duty of the transferor to acquire the necessary legal protection, or ensure the secrecy is maintained of any new technology developed. This of course refers to the IP involved in such a research undertaking and can be seen to represent the IP strategy which was developed alongside this technology transfer strategy. Also included in this model are some measures of effectiveness. The market impact and economic development are drawn from the Bozeman model and are applicable to this industrial strategy in particular, as they form the goal which it aims to achieve. This is of course the development of the South African economy by expanding its titanium machining capabilities. If this is achieved, then not only has the technology transfer been successful, but the entire titanium machining industrial strategy. What is unique in this model is the feedback which the university will gain by studying the effectiveness of the technology transfer. This will allow for the methods of technology transfer to be updated and improved. Although feedback is not strictly an effectiveness criteria in itself, as any feedback, whether it be positive or negative, is useful in making future decisions, it can still be considered one for the purposes of the titanium machining research. This is due to the nature of such a research and development initiative, where relevant feedback can in itself validate a technology transfer, particularly if what is being transferred is being done so primarily to gain an insight into industry.

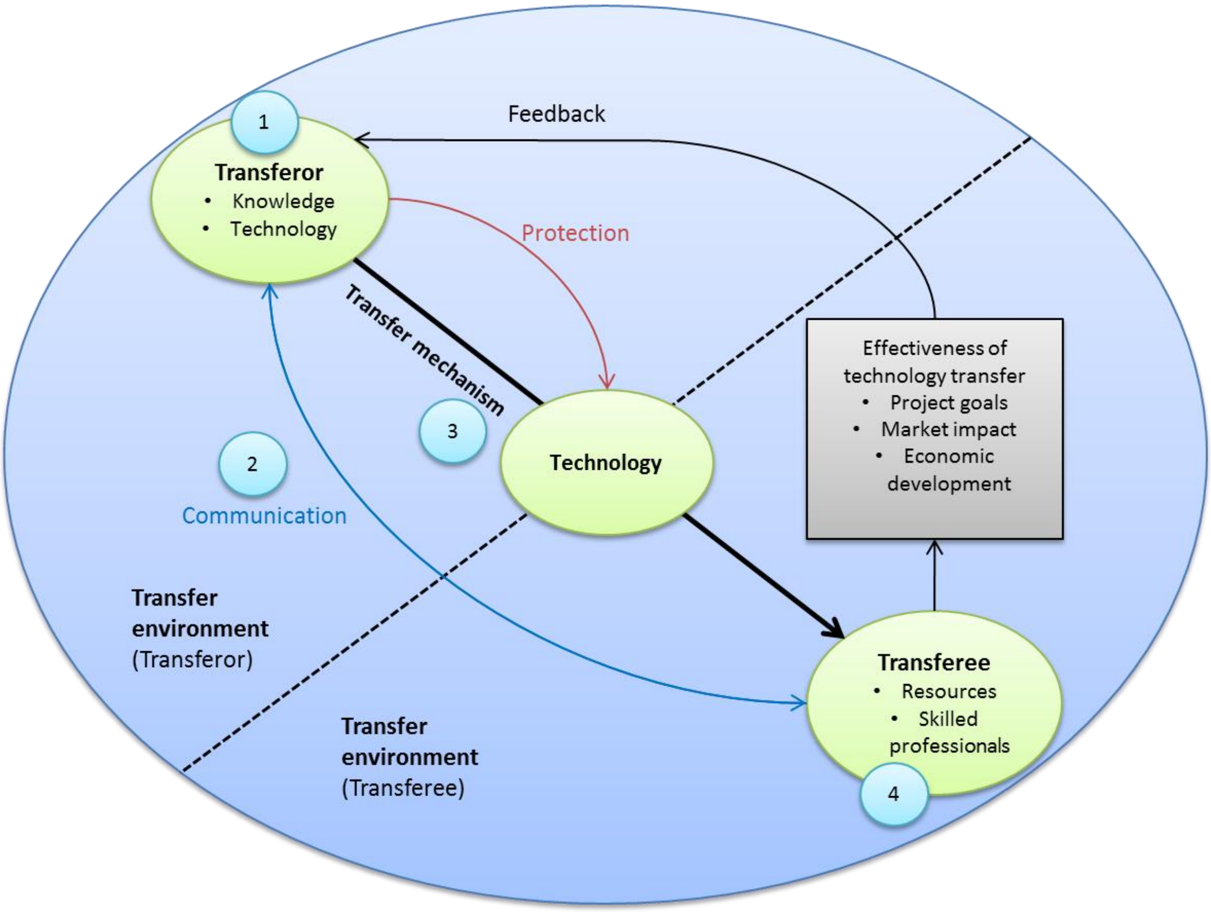

Figure 9: Technology transfer model for the titanium machining research outputs

The numbers shown in the light blue circles represent the levels on which technology transfer can take place as explained in the section on knowledge and technology transfer levels. The first level, creation, is a task which the transferor must undertake. The second level, sharing, is achieved through communication between the transferor and transferee. The third level, implementation, is achieved through a transfer mechanism. In the case of the titanium machining research, this might be something as simple as the university providing the knowledge developed, as well as any new technology developed while the transferee or industrial partners provide the resources, as well as skilled professionals to provide assistance in the operation of those resources. The fourth level, commercialisation, is ultimately the responsibility of the transferee, whose task it is to exploit the new technology to expand the relevant industry. The transferor must however, ensure that the transferred technology is exploited as per any agreements which accompanied said technology.

3.3 Summary

As far as research input is concerned, the titanium machining project “Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications”, neatly packages most of the activities which are to be conducted. Work Package 1 describes five new processes/process combinations which are to be explored together with their respective demonstrators as well as a plan for pilot implementations across three industrial partners. This makes them an ideal example to use as a form of validation for the technology transfer model as was developed in this chapter. The validation can be found in Chapter 5, Technology Transfer Strategy Implementation, of this thesis. Work Package 2 expands upon the progress which has already been made by identifying what still needs to be done in order to provide an extensive conclusion on the topics of high performance machining, metallurgical aspects and near-net shape forming technologies as well as modelling and simulation within the scope of the titanium machining research. Work Package 3 focuses on aspects of commercialisation and technology transfer which will be crucial to transferring technology on the fourth level of technology transfer as described earlier in the chapter.

The plan for research output began by identifying some long term goals which can assist one in sustaining economic growth through the development and commercialisation of new technologies. Keeping these goals in mind while developing a transfer strategy helps one to stay on course by remember the ultimate objectives of technology transfer. These goals work to establish a solid base of operations from which the transferor (the universities conducting the research) can efficiently bridge the gap between invention and commercialisation, while at the same time developing a positive relationship with the transferee’s (the industrial partners).

Policies and practical aspects for university-industry technology transfer were considered next, providing answers as to why ownership of rights by the universities who conducted the research and development is beneficial to the technology transfer process, as well as how internal policies on IP at universities help in building relationships with the private sector. Some of the key points raised in this section which are most relevant to the titanium machining research are:

- Ownership of the rights by the universities provides a clear and predictable way for stakeholders to attain the technology and also facilitates joint research between different organisations.
- A research project with many researchers can create fragmentation of ownership and thereby complicate transfer and commercialisation. Ownership by the university negates this issue.
- University policy ensures that discoveries, inventions and creations generated by staff and students are utilized in ways most likely to benefit the public.
- The responsibilities, rights and obligations of all stakeholders are defined through contractual agreements.
- The development of basic guidelines for the administration of the IP Policy.
- Technology transfer offices enable universities to professionalize their technology transfer activities as well as providing a source of knowledge and support on the topic of intellectual property.

In order to simplify the idea of technology transfer, the different levels on which technology can be transferred were explored. Together with a description of how technology/knowledge is transferred on each level is some information as to what the titanium machining research initiative has produced in this respect. It is on the third level of technology transfer, implementation, where the concept of a pilot implementation at an industrial partner was first explored. It is shown to be an effective means for the initial transfer of technology.

The development of the technology transfer model for titanium machining was preceded by an investigation of some existing qualitative models. These models showed how crucial it is to involve the transferee in all aspects of technology research, development as well as the transfer process itself from the very beginning of any project in which knowledge transfer to industry needs to take place. Another important aspect which needs to be incorporated in the transfer of technology is that of effectiveness criteria. These are not only important for the assessment of the transfer process itself, but can also be useful in directing future research through the feedback of the transferee. As such, some relevant effectiveness criteria were chosen to include in the model developed for this research area. They are:

- Project goals – Although a rather broad criteria, this is used to encompass the individual technical goals of each sub project, for example, in the pilot implementations of the five processes/process combinations we use the near-net shape analysis to assess the need for further surface finishing techniques by evaluating how close the initial production of a part is to its desired final shape.
- Market impact and economic development – These two criteria are useful in that they can determine the effectiveness of the titanium machining research outputs as a whole. Although different for each piece of knowledge/technology the ultimate goal is the same. Has the transfer process enriched the titanium machining industry in South Africa? And as a result, is the economy more profitable? These criteria need to be evaluated through a techno-economic analysis and although they might not be relevant during the early, testing, stages of technology transfer, they will become so as complete technologies are ultimately implemented.

Chapter 4. Intellectual Property Strategy

The intellectual property (IP) strategy described in this chapter is divided into three main sections. First, IP basics and potential issues are covered to provide a basic understanding of intellectual property rights as well as some good IP management practices. The second section explores IP localisation and retention covering licensing, monitoring as well as the contractual agreements in place for the titanium machining research initiative. The third section details a plan for IP output, exploring their potential patentability as well as the policy of InnovUS of on such matters. Each section is concluded with a summary of what has been presented.

4.1 Study of IP Basics and Potential Issues

Although IP is fairly complicated and situational, there are certain basic understandings and options which can be studied. These basics are explored in this section and begin with intellectual property rights, which provide legal protection to ones newly developed inventions or ideas. The focus then shifts towards the management of IP. Good management practices simplify the process of IP protection by defining roles within an organisation and establishing a process for the identification and protection of new IP. This is achieved through an understanding of the organisational roles of an IP system as well as the implementation of an IP portfolio upon which an IP audit can be conducted. The structures which a company or institute can adopt, which essentially determine at which level in the company decisions with regards to IP management are made, are also an important management consideration. Finally some issues with regards to IP are considered, with a focus on those in an environment involving research institutions and industrial companies. Although the information provided in this section is not directly linked to the titanium machining research initiative as it is presented, its purpose is to provide a solid background to IP as well as some solid management practices. The summary, however, links much of the basics explained within this section to titanium machining.

4.1.1 Intellectual Property Rights, an Overview

There are certain legal rights which exist to protect innovation against theft and misuse. These rights are known as intellectual property rights or IPR's. These IPR's include patents, trademarks, designs and copyrights. Also included in this section is information on trade secrets which are not IPR's which one can register although they are an option, however, when it comes to the protection of intellectual property. In South Africa, the IP division, namely, the Companies and Intellectual Property Commission (CIPC), is responsible for the registration of these IPR's. The main functions of the CIPC can be found on their website and are listed below (CIPC, 2011).

- Registration of Companies, Co-operatives and Intellectual Property Rights (trademarks, patents, designs and copyright) and maintenance thereof
- Disclosure of Information on its business registers
- Promotion of education and awareness of Company and Intellectual Property Law
- Promotion of compliance with relevant legislation
- Efficient and effective enforcement of relevant legislation
- Monitoring compliance with and contraventions of financial reporting standards, and making recommendations thereto to Financial Reporting Standards Council (FRSC)
- Licensing of Business Rescue Practitioners

- Report, research and advise on matters of national policy relating to company and intellectual property law

IPR's can often overlap with a consumer product being protected by more than one IPR during its design, manufacture and marketing. Innovation is becoming extremely important in the global economy and can be considered a primary competitive advantage. It is for this reason that IPR's are essential to maintaining an edge over competition in the research and development sectors not only in South Africa, but on a global scale. Many different industries across our economy rely on the adequate enforcement of their patents, trademarks, and copyrights to protect their IP. It is not only industry that is concerned with IPR's as consumers also use them to determine where to spend their money. Strong IP rights help consumers make an educated choice about the safety, reliability, and effectiveness of their purchases as well as ensure products are authentic, and of the high-quality that consumers recognize and expect. IP rights foster the confidence and ease of mind that consumers demand and markets rely on (Global intellectual property center, 2009).

4.1.1.1 Copyright

The Berne convention for the Protection of Literary and Artistic Works, or Berne convention as it is commonly known, covers copyright law for most countries in the world including South Africa. Article 1 of the Berne convention states: The countries to which this Convention applies constitute a Union for the protection of the rights of authors in their literary and artistic works.

Copyright arises automatically by law. This means that there is no registration required. Copyrights do not protect ideas or concepts or intangible assets, but rather protect the way in which the idea or concept is expressed. Instead, the way in which it is written or drawn is protected. In order for a copyright to exist, the work must be original and must be the product of skill or labour invested by the creator (Irish, 2005).

Copyrights provide protection for the following works, assuming they are original:

- Literary works;
- Musical works;
- Artistic works;
- Cinematograph films;
- Sound recordings;
- Broadcasts;
- Programme carrying signals;
- Published editions;
- Computer programmes.

Artistic works include drawings, paintings, sculptures, engravings and photographs, as well as works of architecture and works of craftsmanship. Drawings are of particular interest on an engineering level as both engineering and industrial design drawings fall into this category. Copyright only protects a particular rendition of a design which has been reduced to material form and not the underlying concept (SABS design institute, 2008).

The owner of a copyright is usually the author or creator of the work, unless they are employed under contract or apprenticeship. In the case of employment, the employer becomes the owner of the copyright. Copyrights can, however, be transferred or licensed. A copyright generally lasts for the life of the author and an additional 50 years after his or her death. In the case of photographs, films and computer programmes, the copyright will last for 50 years after the work has been made available to the public with consent of the author (WIPO, 1979).

Copyrights provide protection by preventing others from making copies of the copyrighted work as well as protection against distortion of the work in such a way that it would be detrimental to the reputation of the author. Publishing copyrighted work or selling it is an act of direct infringement. The work copied must be similar to the original work in its expression and not a copy of the idea. As mentioned earlier, copyrights protect the way in which the idea or concept is expressed.

It is important to date all original drawing as well as have them witnessed. The copyright symbol and notice should also be added to all original drawings of new designs. The automatic copyright which will arise can often protect the design if the designer forgets to register it or information is leaked before registration can take place.

4.1.1.2 Design Registration

The word design is defined in the Oxford Dictionary as “a plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is made”. The definition mentions the “look and function” of an article which relate to the two types of designs which can be registered in South Africa. The designs act no. 195 of 1993 makes provisions for the registration of both aesthetic and functional designs. The first design right is an aesthetic design which according to the designs act no. 195 of 1993 has a unique shape, configuration or ornamentation that appeals to the eye. The second is a functional design which has a shape or configuration that is necessitated by its function (CIPC, 1997). A single design can be protected for both aesthetics and function as long as both criteria are fulfilled. An aesthetic design registration will last for 15 years, while a functional design will last for 10 years. Both are subject to payment of annual renewal fees after the third year (Hahn and Hahn Inc, 2011).

With design rights it is essential to register as soon as possible. Absolute novelty is required for both aesthetic and functional designs. For a design to be considered ‘new’ it must not form part of the state of the art immediately before the date of application for the registration or the release date, whichever is the earlier (SABS design institute, 2008). The release date is the date on which the design was first made available to the public. There is a 6 month period of grace between the release date and the date on which the design must be registered in the case where the release date is earlier. The state of the art includes all matter which has been made available to the public anywhere in the world by written description or by use in any other way (Spoor and Fisher, 2013).

The owner of a design right may apply for a monopoly right. The design right may also be assigned to a person or company for whom it was made. The effect of registration of a design is to grant to the registered proprietor in South Africa, for the duration of the registration the right to exclude other persons from the:

- Making;
- Importing;
- Using;
- Disposing (selling);

of any article included in the class in which the design is registered and embodying the registered design or a design not substantially different from the registered design (Innovus, 2013).

A South African registered design has effect only in the territorial area of South Africa. If protection is desired in other countries, applications should be filed in those countries. South Africa, as one of the countries to whom the Paris Convention applies, benefits from the ability to register in further countries up to 6 months after the basic registration in this country. Section A, number 1 in article 4 of the Paris Convention states “Any person who has duly filed an application for a patent, or for the registration of a utility model, or of an industrial design, or of a trademark, in one of the countries of the Union, or his successor in title, shall enjoy, for the purpose of filing in the other countries, a right of priority during the periods hereinafter fixed.” Section C, number 1, also in article 4 of the Paris Convention states “The periods of priority referred to above shall be twelve months for patents and utility models, and six months for industrial designs and trademarks (WIPO, 1979).”

It is important to note that the protection provided by registration of a design is restricted to the nominated class or classes in which the design has been registered. The scope of the protection provided by a design right is based on the novelty of design. If there is a large difference between the design and prior art then the scope of the protection will be broad whereas if the difference is small, the scope of the protection provided will be narrow (Innovus, 2013).

4.1.1.3 Patents

A patent is an exclusive right granted for an invention, which is a product or a process that provides a new way of doing something, or offers a new technical solution to a problem (CIPC, 2011). Similar to design rights an invention is deemed to be ‘new’ if it does not form part of the state of the art immediately before the priority date of the invention (CIPC, 2002). Because of this important fact, the first thing which must be done before considering filing for a patent application, is to search existing patents to ensure that one does not already exist. Any disclosure before a patent application is made, whether by publication, exhibition or the selling of a product which incorporates the technology, means that the invention is no longer considered new. Adams and Adams attorneys describe this necessity for secrecy in their patents for inventions document as follows: “A non-confidential disclosure of the invention before the patent application is filed may destroy the novelty of the invention and can rule out any hope of obtaining valid patent protection for the invention (Adams & Adams, 2012).” It is for this reason that filing a patent for an invention before disclosing the invention is essential. Many patentable inventions forfeit protection because the inventor did not know this. Another lesser known fact with regards to patents is that not all patent applications need to be for major breakthroughs in technology. Improvements on existing products or processes may also qualify as potential patents (Irish, 2005).

Patents, as with other IPR’s, provide more than just protection to an invention. They are also important management tools which can be formidable assets to a company in a competitive sense. They can often provide a company with an advantage so large that competitors find it extremely difficult to keep up. It is becoming more common that a company’s patent or IP department is viewed as a source of profit rather than a department which incurs costs (Arai, 2000). As such it is no surprise that patent applications around the world continue to increase every year. This trend is shown in Figure 10 and includes the yearly growth rates.

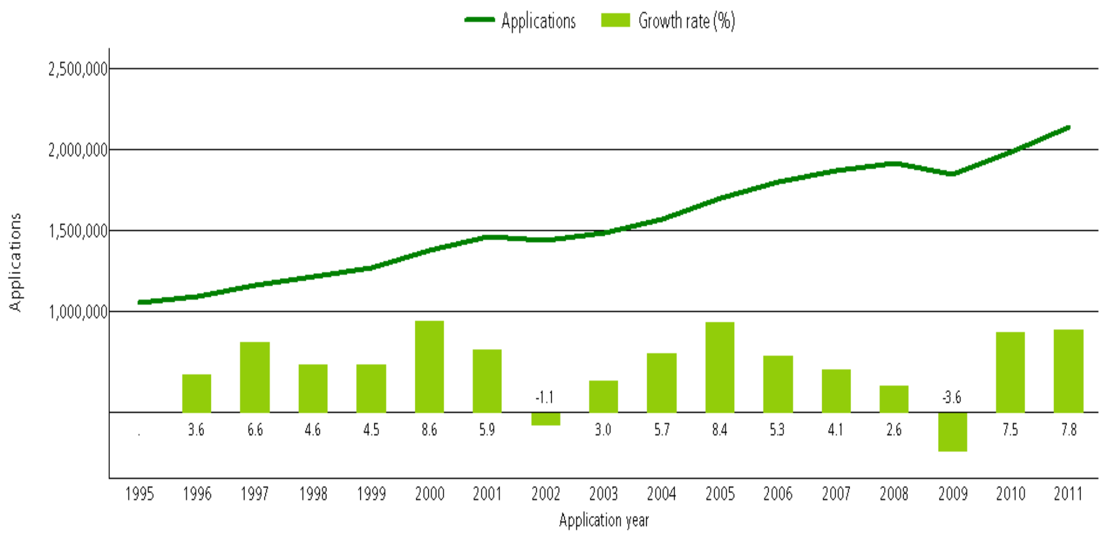

Figure 10: Trend in patent applications worldwide (WIPO, 2012)

The patents act No.57 of 1978 provides for "the registration and granting of patents for inventions and for matters connected therewith (CIPC, 2002)." A patent is most commonly a national monopoly right valid both for a limited period of time and to the nation concerned. Regional patents do exist, for example, a European patent can be obtained through the European patent organisation (EPO) which will then grant the patent rights for the invention in the countries who form part of said organisation. In the case of a South African patent the effect of said patent is to grant to the patentee the right to exclude all other persons, in South Africa, for the duration of the term of the patent, from:

- making;
- exercising;
- using;
- disposing of (selling);
- offering to dispose of (advertising);
- and importing

the patented invention (Innovus, 2013). There are certain exceptions to patent protection, most notably, a method, scheme or rule of doing business or playing a game; a scientific theory or mathematical method; the presentation of information; a computer program, and methods of medical treatment (SABS design institute, 2008). These excluded categories can be protected indirectly by the patenting of technology necessary for their success. With regards to ownership, the inventor will own the rights to the patent unless he gives the rights over to an assignee. The rights to a patent may also be assigned to the employer of the inventor if the invention was made in the course and scope of the employment.

Provisional application can be made in South Africa and obtains provisional protection for a period of 12 months in over 150 countries that form part of the Paris Convention. Section A, number 1 as well as Section C, number 1, both found in article 4 of the Paris Convention describe this and have been quoted in the design right section of this chapter. A complete application then needs to be filed in selected countries before the 12 month period of provisional protection expires. Protection is generally granted for 20 years from the date of filing the complete application and is usually renewable from the 4th year. This applies to each country in which the complete patent application was filed and accepted in.

A popular alternative to the above method for foreign patent application is to file a patent co-operation treaty patent application, or PCT, which facilitates certain steps in the process of obtaining patents internationally. The PCT establishes a procedure for the filing and processing of a single application for a patent which has legal effect in the countries which are treaty members (WIPO, 2007). This includes over 148 contracting states as of the 4th of October 2013. These contracting states can be found in Appendix 3: PCT contracting states. The contracting states are highlighted blue in Figure 11 and can be seen to include South Africa.

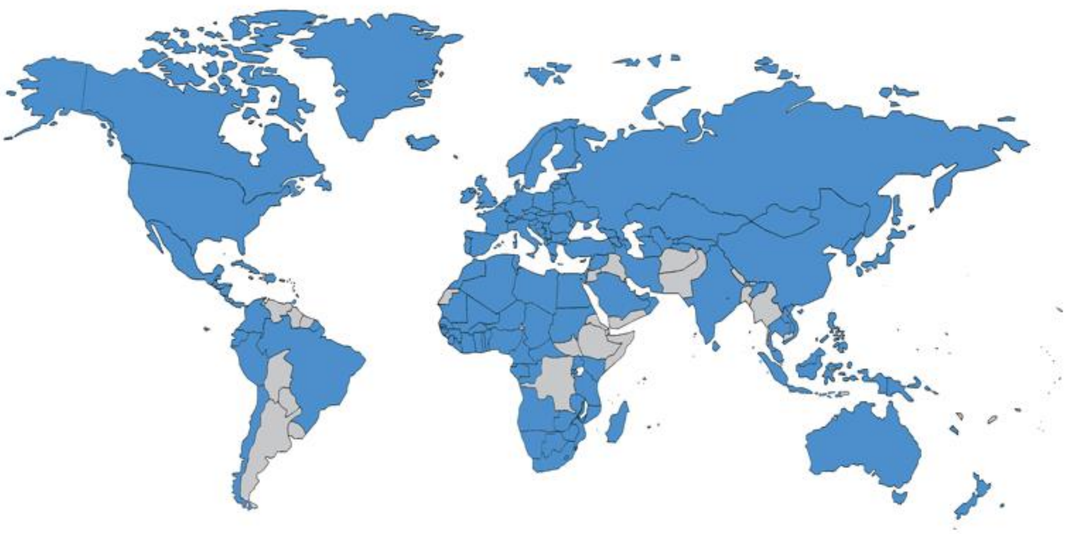

Figure 11: PCT contracting states (WIPO, 2013)

The PCT simplifies the procedure for obtaining patent protection in the countries who form part of the treaty, making it more efficient and economical for both the applicants/inventors as well as the patent offices in each respective country (WIPO, 2007).

The PCT extends the period of provisional protection from 12 months to 30 months. Its advantages include deferring the costs of filing in foreign countries and an early and reliable indication of validity with an opportunity to make amendments if necessary. Ultimately the PCT procedure will leave the patent application in a better condition to successfully pass the examination in each country in which the inventor chooses to patent (SABS design institute, 2008). How the PCT system works is shown graphically in Figure 12.

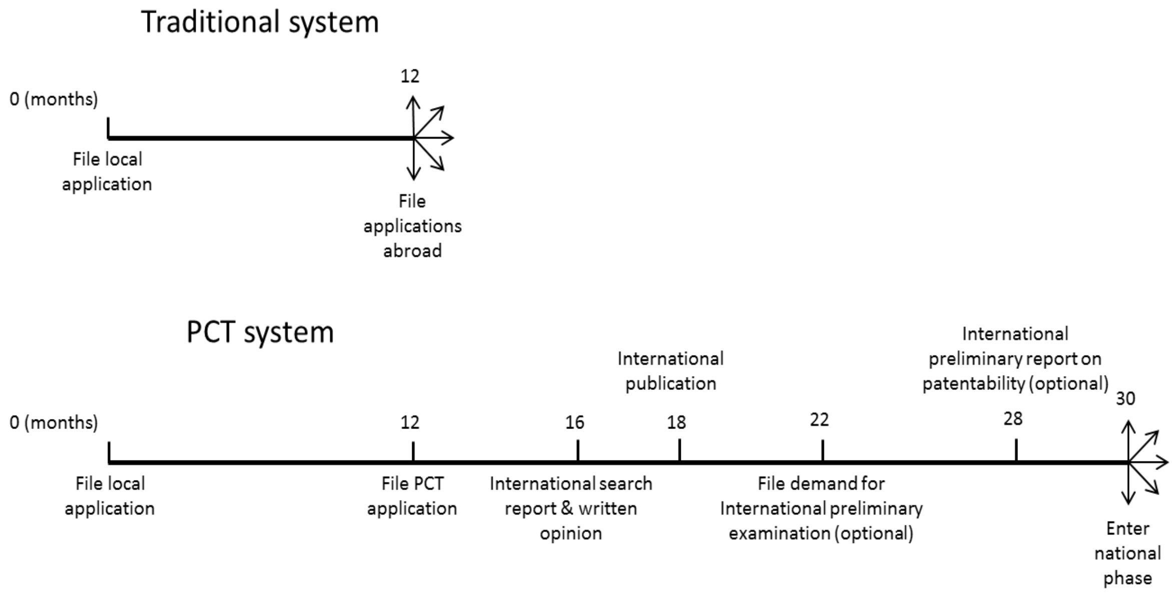

Figure 12: Traditional vs. PCT system for patenting (WIPO, 2007)

Some additional information with regards to the steps in the PCT system is described below:

- File local application (month 0): This is typically a national patent application which would be filed in South Africa in the case of the research being conducted for titanium machining. Application is typically performed through the patent department of the company or university in question who will then file an application with the CIPC.
- File PCT application (month 12): This application is filed at the same national patent office as the local application with a uniform set of requirements including fees, language and formality. Legal effect applies to all the states that form part of the PCT.
- International search report and written opinion (month 16): A report on the state of the art as well as an initial patentability opinion is given. This will detail whether the invention is patentable or whether it exists somewhere in the world already.
- International publication (month 18): The content of the application is disclosed to the world in a standardised format.
- File demand for preliminary examination (month 22): If any amendments are made to the application it is at this point that an additional patentability analysis is requested.
- International preliminary report on patentability (month 28): An additional patentability analysis is performed with the purpose of assisting in national phase decision making.
- Enter national phase (month 30): It is at this point that intent to patent in various states is expressed and the relevant steps are taken.

Information which the PCT process provides to the applicant can be used to make decisions about whether or not to enter the national phase, as well as where to enter it, should they wish to do so (WIPO, 2007).

In some rare situations one might choose not to file for patent protection and rather keep their inventions a secret. This will ensure that the inventor will have monopoly rights well beyond the 20 years of protection which a patent can provide. It is only a good idea to choose this course of action if it will not be possible for outsiders to analyse and determine your invention. Another risk with this option is the possibility of an insider revealing the secret (SABS design institute, 2008).

4.1.1.4 Trademarks

A Trademark is the means by which a business makes itself visible in the marketplace according to Pipers patent attorneys (Pipers patent attorneys, 2012). It may consist of any sign capable of being represented graphically, including:

- a device;
- label;
- name;
- signature;
- word;
- letter;
- shape;
- configuration;
- pattern;
- ornamentation;
- a container for goods, or any combination of these (SABS design institute, 2008).

The purpose of a trademark is to distinguish the products/services of one company or person from the products/services of another company or person. The distinguishing function is an important element of trademark law. A successful trademark is instantly recognisable and both existing as well as potential customers associate them with things like quality, reliability and the source of the product or service. Apart from the ordinary trademark which has been described so far, there also exist certification marks, which are usually used to certify that particular goods or services have particular characteristics. Another type of trademark is the collective mark, which shows that a member of a particular association provides the goods or services associated with that specific association/organisation. A collective trademark as such would be registered by a group of traders (WIPO, 2013).

It is possible to devise and use one's own trademark without registration. However, many of the benefits which accompany the use of a trademark, is obtained through its registration. In South Africa the trade marks act no.194 of 1993 makes provision for the registration and governs the use of a trademark. The effect of a registered trade mark is that other people may not use a confusingly similar mark in relation to goods or services identical or similar to those for which the trade mark is registered (Innovus, 2013). Other advantages provided by the registration of a trademark include:

- Acting as a deterrent to prospective infringers;
- Forming the basis of an objection to an application by another to register a confusingly similar trademark;
- Making provision for infringement by use of a trademark, which is identical or similar to a registered trademark if that use would take unfair advantage of or be detrimental to the distinctive character or repute of a registered trademark (SABS design institute, 2008).

A registered trademark, unlike other forms of IP, can last forever assuming that it is renewed every 10 years, calculated from the date of filing. It must also be kept in mind that, if a trade mark is not used for a long period of time, it is vulnerable to being removed from the register. In South Africa this period is 5 years. Another risk to consider is the possibility of one's trademark becoming generic (Innovus, 2013). Examples of this include the Escalator, Yo-Yo and Sellotape.

A trademark is only effective in the country in which it is applied for in. If regional protection is desired one might consider applying under the Madrid protocol in which case trademark protection will be acquired in a number of countries around the world. These contracting states can be found in Appendix 4: Madrid protocol contracting states. Another option also exists which provides protection throughout the European Union; this is known as a community trademark or CTM.

4.1.1.5 Trade Secrets (Know-How)

A trade secret is a commercially valuable piece of information which is kept confidential. The value of this information is almost entirely based on it being kept a secret. Examples of such information can include:

- research results;
- unpublished research reports;
- tender prices;
- computer software;
- production processes;
- know-how;
- customer lists;
- technology schematics of a manufacturing process (Water research commision, 2008).

Trade secrets come in two forms. The first is a trade secret which concerns inventions or manufacturing processes that do not meet the patentability criteria and therefore maintaining confidentiality is the only way in which they can be protected. The second kind is a trade secret which concerns inventions that would fulfil the patentability criteria and could therefore be protected by patents (WIPO, 2013). It is in the second case that a person/company will have to make a choice as to whether or not they wish to patent their invention or keep it a secret.

Trade secrets have both advantages and disadvantages when compared to patents and are described below (WIPO, 2013). First let us consider some advantages:

- Trade secrets last for an indefinite amount of time, that is, for as long as the secret is not revealed to the public. A patent on the other hand will last for around 20 years.
- There is no registration or renewal fee associated with trade secrets although one should be mindful that in order to keep the information confidential, unexpected costs may arise.
- Trade secrets are effective immediately and do not require compliance with formalities such as disclosure of the information to a government authority.

The disadvantages of trade secrets are particularly important to consider especially when the invention concerned would fulfil the patentability criteria:

- If the secret is embodied within an innovative product, others may be able to reverse engineer it in order to discover the secret. If they are successful, they will then be entitled to use it personally or even commercialise it.
- Once the secret has been made public, anyone may have access to it and make use of it.
- The level of protection granted to a trade secret is considered weak when compared to the protection granted by a patent.
- A trade secret may be patented by someone else who developed the relevant information by legitimate means. The person who develops and patents the invention could then take legal action against the trade secret holder.

In order to maintain the secrecy of one's trade secrets, contractual agreements with all employees who will be privileged to the confidential information will have to be put in place. An important fact to remember is that a restriction on the use of information that is not truly of a confidential nature and which prevents the employee from applying his skill and knowledge in competition with his former employer, is void and unenforceable (Water research commision, 2008). Although an employer's rights to his trade secrets are protected, former employees are entitled to use their skill and experience to attain similar results in their future employment. This is one of the main reasons that choosing to protect information with a trade secret rather than with a patent is extremely difficult.

4.1.2 IP Management

Having a solid base for managing IP is essential for any research and development undertaking. In this section we consider the IP portfolio and audit, one of the first tools one would need to use in order to manage IP. The organisational roles of an IP system are then considered, followed by an exploration of different structures which can be used within an organisation which intends to manage IP rights.

4.1.2.1 The IP Portfolio and Audit

Before a decision on how to manage IP can be made, an IP portfolio needs to be compiled. The IP portfolio is basically all the IP which a company or institute owns, identified and classified to provide a basis for decision making in an IP strategy. It should include all IPR's, trade secrets and other intangible assets owned such as licensing and contractual agreements. Once an IP portfolio has been compiled, an IP audit can be conducted to identify the status of the IP concerned. The questions posed below need to be answered in order to successfully conduct an IP audit and provide one with a platform to conduct further IP management decisions (Rahmy, 2005).

- Have all of our IP assets been identified?
- Are any of our IP assets able to be registered? If so, do we want to register them or manage them as confidential information?
- Is any of our IP registered in foreign markets? If not, where would we like to have protection?
- Is there any IP which other people or company's own which we currently use or intend to use (license agreements)?

Other important factors which need to be considered when developing an IP strategy are detailed below. These are more easily addressed once the IP portfolio and audit have been completed. These considerations include:

- How important IP assets are to the success of one's business. This entails evaluating ones current IP assets and estimating their future worth. It also entails identifying the competitive advantage which the IP assets one owns provide.
- How IP assets are protected is an important consideration. This includes deciding whether or not to commercialise ones assets or to simply maintain sole ownership over them. If IP is licensed, contractual agreements must be implemented to ensure that the rights are used and protected as desired.

4.1.2.2 The Organisational Roles of an IP System

An IP system, once in place, has certain practical roles. These roles include acting as an incentive system for innovation, packaging intellectual assets, diffusing technical information and controlling intellectual assets (Pitkethly, 2007).

An IP system acts as an incentive or reward system for innovation through the power that comes with protection. Protecting innovation by restricting use by others provides the inventor with command over the invention. How the invention is marketed and the price at which it is sold can be dictated by the inventor up to a point, with consideration of the IP's valuation. It is important to note that, although control is conferred though protection, it can be used to both limit and expand the market for innovation.

With technology based innovation, as is the case with the titanium machining research initiative, IP systems can help to package and define intellectual assets. Intellectual assets, defined as intangible assets, such as experience, knowledge and skills, often start as tacit ideas formed by the inventor. In order for these ideas to become useful, they need to be packaged in such a way that they become more easily transmissible and protectable. An IP system allows previously tacit or secret information to be identified and made the subject of transactions and communications. This ability allows us to use our IP to our benefit more effectively. It also helps ease any lack of trust which might exist when IP is to be traded, as the use of IP rights and legal contractual agreements ensure that one knows exactly what is to be expected from the deal.

The ability to diffuse technical information is achieved by an IP system which reduces the threat of IP thieves and competition. In the past, an innovator may have been tempted to keep an invention secret. This invention may have been important to the development of technology; however, as it was not made public, the development could not take place. In some cases society might be denied potentially lifesaving technologies. Today the IP protection available, especially the patent system, allows new inventions to be published and information regarding the invention to be more easily found. The rights granted to innovators provide them with protection and control over their inventions, but at the same time, allow others to study them.

The last of the mentioned roles of an IP system is the control of intellectual assets. In the case of the titanium machining research, this is particularly important as it is a government funded industrial strategy with the ultimate goal to benefit the public of South Africa. As mentioned before, IP rights provide a means to both hinder the use of an invention as well as to allow it to be licensed out and stimulate the economy. If IP rights are not attained for an invention, major strategic implications may result.

4.1.3 IP Structures

In this section the different structures which can be the basis of a successful IP strategy are explored. First we consider the way in which the IP is managed within a company by looking at two organisational structures. These help us to decide at what level of management the decisions with regards to IP should be made. Focus is then shifted to the external and internal aspects of IP. The external strategy identifies the aspects of the company or institute which focus on interactions with other parties. The internal strategy identifies aspects which should be considered within a company or institute that is managing IP.

4.1.3.1 Centralised vs. Decentralised Structure

Having managers in a company who understand IP and are able to create strategies and manage IPR's is not always enough for effective IP management. Strategies will always need to be accompanied by effective management structures and implementation tools. The organisational structures governing the management of IPR's are generally either centralised or decentralised. This section is based on the centralised and decentralised structures as described by Bryer, Lebson and Asbell in the book Intellectual Property Strategies for the 21st Century Corporation (Bryer, et al., 2011).

In a centralised structure the decisions are made centrally by a few individuals with others providing support. Decisions are made at the top level of organisation and then designated people/departments are given the task of implementing those decisions. This type of structure is represented graphically in Figure 13.

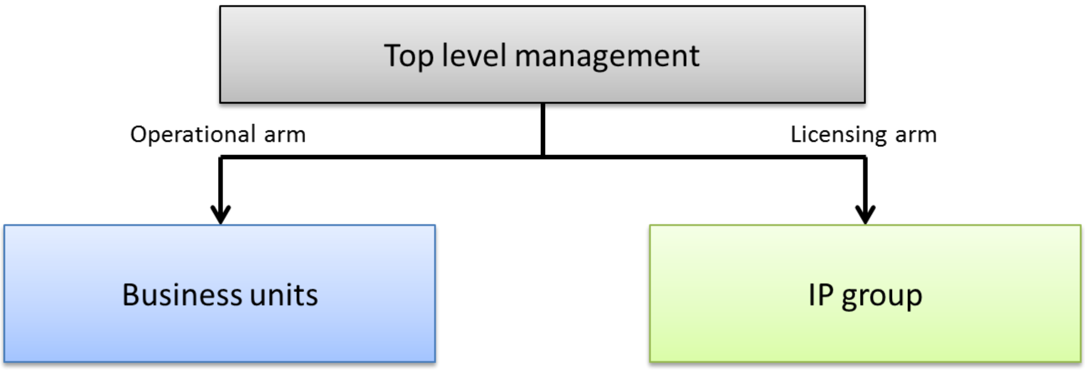

Figure 13: Centralised IP management structure (Bryer, et al., 2011)

This structure is useful for cases in which the IP is complex and there are many licensing agreements and potential future litigation issues. The IP group receives its orders with regards to the management of the company's IP from the top level of management. It must then coordinate with the business units as well as third parties to achieve the IP goals which have been set. This structure avoids duplication as it has a single department managing all of the company's IP, however, it is important to consider that the single department might not have the information required to always make the right decisions. A single IP group might not always have the insight of a smaller, more specialised IP department.

In a decentralised structure there are by contrast multiple, potentially competing decision makers. In this structure the decision making process is localised at certain levels within the organisation. This type of structure is represented graphically in Figure 14.

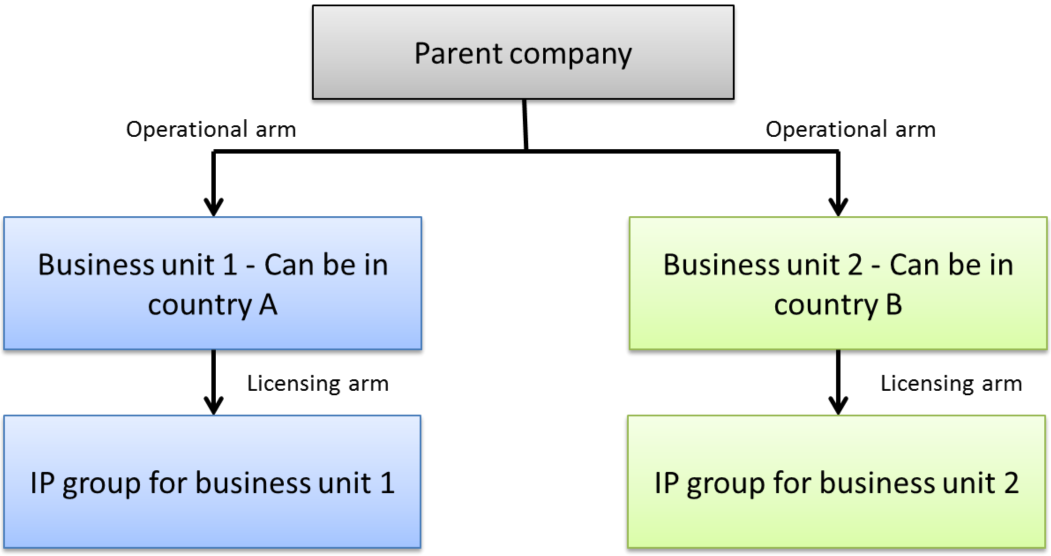

Figure 14: Decentralised IP management structure (Bryer, et al., 2011)

In this structure the IP issues are less complex and the need to leverage business know-how across the business units is not strong. Each business unit is responsible for the management of its own IP and must use its resources as needed. Decisions in this structure are made on a local level therefore promoting greater employee involvement and input.

4.1.3.2 External and Internal Strategies

An IP strategy has both external and internal aspects to consider. The external aspects involve the activities of the company or institute which focus on interactions with other parties. The internal aspects involve the activities which focus on IP management within the company or institute. Both are however important as they are concerned with the value and allocation of IP resources. This section is based on the internal and external strategy as explained by Robert Pitkethly in his handbook of best practices (Pitkethly, 2007). The strategies presented here explain how one should manage their own IP; it does not include strategies on how one should acquire IP. The structure is represented graphically in Figure 15.

First let us focus on the external strategy. The key components here are the issues of exploitation (with a focus on licensing) and litigation. Litigation and licensing are opposites in the sense that litigation prevents an infringement of IP rights whereas licensing allows others to make use of them. Although they are opposites they provide options to the IP holder. A decision needs to be made as to which would be most beneficial in achieving the goals of said IP holder in a certain scenario. Decisions with regards to licensing specifically should be driven by licensing considerations in mind rather than the desire to avoid litigation. This should be the mind set of any company or institute whose aim is to maximise the use of their innovations. This is the case with the titanium machining research, where the goal is the commercial stimulation and technological advancement of the South African titanium machining industry. When seeking to exploit ones IP, there exist three main options, these include:

- The outright sale of ones IP rights and technology;
- The exploitation of the technology in house using resources owned to develop and market the products/services;

- Licensing out the technology.

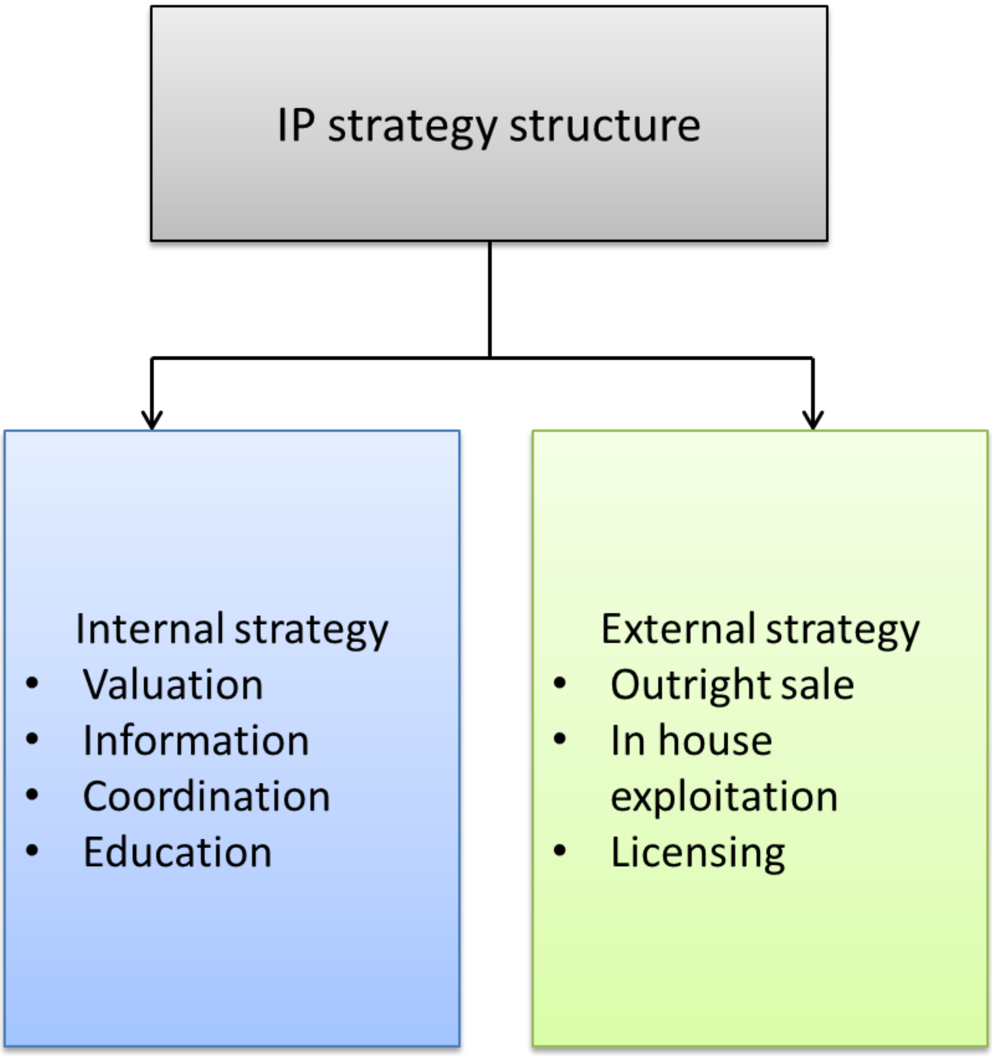

Figure 15: IP strategy structure showing internal and external considerations

Each of these options has their own managerial and organisational implications as the risk and potential reward of each case is different. A key question which has to be answered is that of resources available. What resources are required to successfully exploit the technology? Access to certain assets and skills might be required to exploit the technology in house. These resources might include process development, testing, engineering, production facilities, distribution chains and marketing skills. These resources may not be available to the company or institute therefore limiting their capability to exploit the technology developed in house. If international exploitation is desired the need for resources grows substantially. Although there is potentially more to be gained from exploiting technology in house than by licensing, licensing can make access to potential markets more of a reality. There are alternatives to licensing which one should consider. These include joint ventures, alliances and even a full merger and acquisition. Although licensing is in most cases the easiest course of action it may not be the most efficient at maximising control and returns.

Outright sale involves the loss of control over the innovation and can fix the return available. An alternative is an exclusive license where the contract can include an option allowing the innovator to benefit from unexpected increases in revenue as well as new opportunities to exploit the invention. By choosing this option we limit our downside risk while taking advantage of any unexpected upside advantages. Another alternative to outright sale is to license the technology to a spin-off company who will then develop the technology independently. This would, however, require additional financing. If successful the spin-off company could provide higher returns and enable exploitation on a scale which would have been impossible by either licensing or selling the technology to other companies.

The internal strategy focuses on issues related to certain aspects essential for successful IP management within one's company, these are:

- Valuation;
- Information;
- Coordination;
- Education.

The valuation of IP assets is often very difficult as it requires one to speculate about an inventions future prospect. With this in mind we consider two strategies for the valuation of IP. The first requires an assumption to be made by the innovative company or institute. This assumption is that although there will be expenditure on research and development as well as on IP protection which could go wasted, there will be enough success to more than pay for the failures. This option is often adopted by larger companies who can afford to follow such an approach. The second option involves a case by case analysis of each invention. Patent attorneys as well as IP managers need to make implicit decisions regarding the future value of the inventions. If they foresee the production of an income stream in the inventions future, they will then file for the relevant IP rights in order to protect them.

One of the major roles of an IP system, and IP rights in particular, is to assist in diffusing information. This was described earlier as one of the organisational roles of an IP system. This is achieved by promoting public benefit by forcing inventors to disclose their inventions to the world in return for the grant of a patent or design right. However publishing has its drawbacks and as such is an issue which needs to be considered in the internal IP strategy. Although publishing is of great benefit to the company or institute who invented the new technology, it can also be a source of information to its competitors. Patent searches should always be conducted along with literature studies when considering a publication of new information. Patent searches are often the first available publications when researching competing technology. Apart from allowing one to establish what already exists in their field of technology they also provide one with a sense of the technical trajectory of other organisations. This is important strategic information to possess. It can be useful when dealing with competitors and negotiating licensing deals by providing an insight into where their organisation is heading and what they wish to achieve.

In order to manage IP in a strategic manner within an organisation, the people involved in the development of the technology, as well as those who are responsible for the IP that comes with innovation, need to coordinate effectively. Human resources which need to be allocated can include legal specialists such as patent attorneys, skilled at drafting IPR applications, lawyers specialising in contracting and litigation, as well as research and development managers whose job it is to motivate continual innovation within a company, institute or project. With the research into titanium machining, coordination needs to extend from the university to the investors (the DST) and the industrial partners. Communication between all parties is essential to ensure that the right decisions are made with regards to the management of IP.

The final aspect for a successful internal IP strategy is education. It is essential that there exist a minimal level of IP awareness of training for all those involved in the development of new technology. This is to avoid employees compromising valuable IP before the appropriate level of protection has been obtained. It also provides an improved level of communication between the researches and the IP specialists. The level of knowledge required is fairly low, essentially the basic IP knowledge required to ensure that new IP is not disclosed prematurely. The aim is to dispel ignorance without attempting to turn all employees into patent attorneys.

4.1.4 Potential Issues

It is important for one to know where potential IP issues might arise when developing new technologies. The following section describes some issues which might arise in a university environment and also provides some suggestions as to how to avoid them. The issues discussed include IP knowledge and the damage that can be done to one’s IP before the decision to seek protection is made, proper documentation, dealing with outside collaborators as well as public disclosure.

The first potential issue which will be considered is that of IP knowledge. A lack of understanding of the basics of IP can result in difficulties in protecting your new technologies as well as licensing it out. These difficulties can be extremely frustrating, time consuming and costly. In a worst case scenario, the errors one makes might result in the complete loss of opportunity to protect the newly developed technology. This, in turn, means that the loss of opportunity to market the new technology is a very real possibility. One might even find themselves incurring liability due to inadvertent infringement of IP protected by others.

Another issue which may arise is that of a lack of proper documentation being kept whilst the new technologies are being developed. Keeping ones work fully documented is essential when potential IP is being developed. Proper documentation will support ones application for IP protection and can be a form of protection in itself as copyright material, which, as explained in the section on IPR’s, arises automatically by law. On the other hand one must also be aware of any copyright material which they might make use of in the development of new technologies. Ensure that you have freedom to operate when using materials, methods, and other resources needed for your project. Freedom to operate indicates that you are free to use these resources and that you are not infringing on the property rights of others.

When dealing with outside collaborators it is important to decide on how IP will be handled before work on the project begins. Important questions to answer include:

- Which part of the project/work will each of the collaborators undertake?
- How will the responsibility and credit be shared amongst the collaborators?
- Who will be the authors on the publications which will arise?

Once a project is underway it is beneficial to reassess these questions as new developments unfold, ensuring that all parties are on the same page with regards to the management of IP throughout the project. Problems with regards to IP will most likely arise if these questions are not answered until a discovery is made.

Confidentiality agreements between all parties concerned can regulate the disclosure and use of confidential information which may need to be shared. These kinds of agreements should, for obvious reasons, be implemented before any proprietary information is shared or requested. Not only do these agreements apply to the collaborators of the project but also to any industrial partners who might wish to license the newly developed technology. Confidentiality agreements are usually drafted by the technology transfer office when a university is developing the new technologies. This ensures that the confidentiality agreement is properly drafted as well as signed by the correct individuals.

Unintended public disclosure is another IP issue which can be a particularly frustrating one when it comes to universities. Public disclosure occurs when an inventor reveals previously undisclosed or secret information to those outside the members on the developmental team. In a university setting this can be particularly challenging as disclosure and transparency are essential to the development of projects. Functions of importance to a university such as educating students, publishing and efforts to acquire grant funding are not usually found in the corporate environment. These functions can often lead to unintended public disclosure which can in turn have serious ramifications with regards to the protection of IP.

4.1.5 Summary

Any new developments which stem from the titanium machining research area will most likely be either a new technological invention or some new form of know-how which has been discovered through solving the different problems associated with the machining of titanium. Due to the nature of the research however, it is most likely that IP will be in the later form of know-how, which is defined as practical knowledge or skill. This is because solutions are being explored using existing technologies on the same machines which are currently being used to machine both steel and aluminium. This approach makes the integration of the research into industry more viable. The industrial partners already have machines capable of machining titanium, however the methods used on metals like steel and aluminium are not appropriate for the machining of titanium.

It is still important to consider methods of IP protection for new inventions, as it is not unusual for innovations to surface in research and development initiatives such as this one. For the IP protection of new technologies it would be best to consider filing for a patent, however, one must understand that there are certain requirements to fulfil. The most important requirement being that the invention is new, meaning that it does not form part of the state of the art. If the possibility of a patent does arise it would be wise to consider a patent co-operation treaty application, or PCT. This facilitates the process of obtaining patents internationally, extends the period of provisional protection and provides large scale international protection in a single application. One might argue that for the titanium machining research being conducted, international protection might not be required as the outcomes thereof are localised to South Africa. This is a perfect example of how IP protection is extremely situational and dependant on what exactly the new innovation is as well as how the inventors wish to exploit it.

As far as IP structure is concerned, the titanium machining research and development follows that of a centralised structure where ultimately it is the professors, leading the research at Stellenbosch who will make the decision as to what becomes of the IP which emanates from the work. The business units of the centralised structure in Figure 14 are essentially the different research areas of the larger titanium machining industrial strategy and the IP group is InnovUS, the universities technology transfer office, which is described in more detail later in this chapter.

External and internal strategies as explained in this chapter are an important link to the titanium machining research as they provide guidelines as to how, and by whom, IP will be handled within the university. As far as the external aspects are concerned, which deal with exploitation of IP, there is a unique mix of the options described. In house exploitation is essential to the development of the industrial strategy as a whole. New technologies or know-how can easily be expanded upon in the university environment, which has access to many different resources as well as highly skilled personnel. Ultimately, however, the new developments in the field of titanium machining have to reach industry where they can be applied. Therefore, not only will new developments be refined in house but must also be licensed out to the industrial partners. The licensing in this case will not be for monetary gain but might include contractual obligations which ensure that the IP is used in the way in which the titanium machining industrial strategy intends it to be. Licensing is covered later in this chapter whereupon it is further expanded.

The internal aspects essential to IP management are, as described earlier in this chapter, valuation, information, coordination and education. It is the business of InnovUS to handle the valuation of any new IP presented to them as well as provide information with regards to existing technology in the field as well as an opinion on how best to protect the specific piece of IP. Coordination needs to extend from the university to the investors (the DST) and the industrial partners as well as coordination between the engineering department and InnovUS. Only together can an effective IP management strategy exist. The final aspect of the internal strategy, education, is the responsibility of the universities conducting the research and this very report to a large degree. Without a basic understanding of IP, the individuals involved in the research may lose the ability to protect their work before they even realise that it should be a priority. By simply reading Chapter 4 in this thesis a basic understanding of IP, its protection and management can be gained.

4.2 Development of Measures for IP Localisation and Retention

In the case of the titanium machining research which is being conducted for the industrial strategy, the government is being represented by the Department of Science and Technology (DST). The research is for the benefit of the South African economy and will be implemented through the local industrial partners involved, who will be receiving the technology and IP developed in return for their involvement in the research. It is clear that there are many different parties involved in the research initiative and as such, IP becomes an important factor to consider. Who owns the IP, how it should be used and with whom it can be shared, are just a few of the questions which must be answered in order for such a research initiative to be successful. In this section, measures for localisation and retention of IP are explored, so that any new technology or know how developed through the research, benefits the South African economy. Initially, technology licensing is explored and is essentially how IP is transferred from the inventor to industry where it can be applied while still allowing the inventor control of the rights. Once new technology has been licensed, one must monitor how it is being exploited and ensure that this exploitation adheres to the contractual agreements in place. Focus is then shifted to the titanium machining research at hand, and describes some of the contracts already in place, as well as how InnovUS plays a large role in the protection of any IP coming out of Stellenbosch University.

4.2.1 Technology Licensing

Licensing is the transfer of an IPR from the owner of said right to another. It allows the party to whom the rights have been transferred to exploit that IPR while the owner of the right retains ownership. Technology licensing can only occur where there is a registered IPR. When ownership of the right is transferred entirely, it is known as assignment of the right. Assignment can occur through the outright sale of the IPR or through a contractual agreement. A licensing deal is done through a legal agreement called a licensing agreement. Licensing can work both ways for a company or institute. Licensing out one's IP will bring with it revenue whilst licensing in IP, will allow one to exploit IP which one might require but is unable or unwilling to develop themselves. Cross licensing agreements involve companies licensing in and out IP for mutual benefit (Nanayakkara, 2010).

Licensing has both pros and cons and will always have at least two parties involved, the licensee and the licensor. First let us consider the pros for both licensor and licensee which are presented in Table 4.

Table 4: Licensing pros (Nanayakkara, 2010) & (Venema, 2010)

Parties involved	Pros
Licensor	• Earn revenue • Expand into domestic and foreign markets • Create standards • Simultaneous use by many • Expand manufacturing • Strengthen relationships with partners • Turning a competitor or infringer into a partner • Realising value from technology outside of core business
Licensee	• Lower costs as opposed to research and development • Fast access to technology and know how • Freedom to operate • Possibility of further innovation • Avoid legal problems • Manufacture standardised products

Now lets us consider the cons, again for both licensor and licensee. These are presented in Table 5.

Table 5: Licensing cons (Nanayakkara, 2010) & (Venema, 2010)

Parties involved	Cons
Licensor	• Possibility of creating competitor • Poor choice in licensee can damage reputation if quality standards are not adhered to • Loss of control of proprietary information • Dependence on licensee to make sales and report honest sales revenue
Licensee	• Royalties add to costs • Secrecy requirement • Administrative burdens • May be obliged to grant back improvements • Technological dependence of licensor • Competitors may have access to the same license therefore removing competitive advantage • Licensor could fail to update technology thereby diminishing its value

Licenses usually have certain characteristics which are presented below (Venema, 2010):

- A limited right to use the intellectual property;
- Little access to the knowledge source;
- The application of a "packaged solution," rather than a customized one.

It is important to note that, although these are the most common characteristics, a license agreement can be flexible and negotiations between parties can allow for specific requirements to be added to the agreement. Technology licensing occurs in the context of a business relationship in which other agreements are often important. It is important to consider in a very practical way how the terms of these related agreements affect each other taking in to account timing, pricing and overall value (WIPO, 2008).

Licensing comes in two forms; an exclusive license and a non-exclusive license. "An exclusive license prevents the licensor from granting the rights to others. From the licensee's perspective, an exclusive license prevents its competitors from using the intellectual property being licensed. From the licensor's perspective, however, an exclusive license entails greater risk, because the licensor is depending on only one licensee to fully exploit the licensed intellectual property (Venema, 2010)." A middle ground can be reached with exclusivity being granted only within a certain geographical territory, a given field of expertise or for a set period of time less than the entire term of the license agreement.

Successful technology licensing occurs only when both parties are able to provide benefits to one another and their interests coincide. Ideally, both parties will have different elements of value to offer, for example, skilled employees, a market that can be commercially exploited, know-how, research facilities and commitments, as well as some form of IP (WIPO, 2008).

Important questions to ask when considering a licensing agreement might include:

- What is the reason for the license agreement from a business point of view? This includes considering what must be gained in order for the agreement to be worthwhile as well as being mindful of the best and worst case scenarios.
- What leverage do I have? Essentially we need to ask why the other party wants this agreement.
- What is the time frame for signing the license? Deadlines which the other party may have to meet must be weighed up against whether or not the agreement will be completed to ones standards.
- What data and documents do we need to hand over as well as receive? Documents which the licensee might need could include specifications, patent abstracts and other information relevant to the technology. Documents which the licensor might need could include sales revenue reports, financial history and other business related information.
- Who will conduct the negotiations?
- Are there any other agreements which will need to be considered? These might include confidentiality agreements, agreements for ownership of new technology which might arise as a result of the licensing agreement, sales goals and quality standards.

Essentially, the scope of the rights which are to be licensed need to be defined in order to protect both parties if any issues arise in the future. Ultimately one should aim for an agreement with which both parties are satisfied.

4.2.2 Monitoring and Enforcing IP Rights

Once an IPR has been obtained, it is important for one to maintain complete ownership of the rights via the implementation of an effective monitoring and enforcement strategy. There are three aspects to focus on to successfully monitor and enforce one's IP, namely:

- Market monitoring;
- Information gathering and recording;
- Responding to unauthorised use through enforcement.

First, we consider market monitoring, where a market monitoring program needs to be implemented by gathering information on any unauthorised use or newly filed applications that may be confusingly similar to ones own registered IP. There are many websites online which one can use in order to search for existing IP rights. For IPR's in South Africa, one can use the CIPC website to search for registered trademarks and patents. These types of searches can be done by any individual; however, many companies prefer to have them done by IP professionals who are better suited to spot an infringement. For Stellenbosch University this responsibility falls upon the technology transfer office, InnovUS. More information on InnovUS is provided at a later stage in this chapter. It is best to conduct such searches at regular intervals. Financial resources as well as the desired level of aggressiveness will determine how frequently and how thorough these searches will be.

The second aspect of information gathering and recording is performed in conjunction with market monitoring. If any unauthorised use is detected, these incidents need to be recorded in a database. Important information which one should keep record of is listed below:

- The date of discovery of the infringement as well as when it actually occurred;
- The infringing products/services which have been advertised or sold;
- Any actions which one has taken in order to cease the infringing activity;
- The identity of the infringing party and any associates they might have;
- How the infringing party and the activity was identified.

Collecting this information has two benefits. It will assist in the preparation and execution of enforcement activities, as well as provide feedback as to which monitoring methods are most effective at identifying infringing parties and their activities.

The final aspect is that of response towards infringing activities and the enforcement of ones IPR's. It is important to be respectful when making initial contact. Simply informing an infringer of their actions is often enough to solve the problem. In most cases they are not aware that their actions constitute an infringement. Individuals or smaller businesses might not always be educated in IP laws and can thus unknowingly infringe upon the IP of others. If this does not work, "cease and desist" letters should be sent. These can be categorised into a few types. An aggressive "cease and desist" letter can intimidate infringers into compliance. It is important to remember that this choice could cast the IPR owner in a negative light in trial and potentially ruin their credibility for potential licensing agreements. Alternatively, a softer more friendly approach can be taken, in which case one could more likely solve the problem with a licensing agreement. This approach might result in no action being taken as the infringer might not take the appeal seriously. The best approach might be one in which the facts are presented and is neither too aggressive nor too passive. Demands should be included; these can be for either the removal of the infringing product or for royalty payments for both products sold in the past and for future products sold. The IPR which is being infringed upon should always be included in these letters as proof that one owns the rights. If these letters are not sufficient to stop the infringement, formal litigation should be pursued.

4.2.3 Technology Transfer Office and Contractual Agreements

In this section we focus on the technology transfer office at Stellenbosch University, InnovUS, as well as the contractual agreements already in place for the research being conducted into titanium machining. Stellenbosch University holds the primary contract for the industrial strategy and will be conducting most of the research for it. It is for this reason that the universities policies on IP and its technology transfer office are of great importance to this IP strategy. As this initiative is being conducted in South Africa and for its benefit, the IP act of South Africa is also studied and relevant information extracted therefrom.

4.2.3.1 InnovUS and the Policy of Stellenbosch University

The protection of the IP at Stellenbosch University is the responsibility of InnovUS, the Universities technology transfer company. In order for InnovUS to effectively perform its function, it requires the staff and students to work together with them in identifying and protecting any IP created at the University. If we consider the internal strategy as described earlier, InnovUS will be able to provide assistance with regards to the valuation and publishing of IP information. However, it must be the responsibility of the researchers in the engineering department to ensure there is coordination between InnovUS and themselves, as well as a basic level of IP education to ensure IP is protected before it is registered.

InnovUS offers the staff and students the following services in respect of the utilisation of inventions, designs, business concepts and other IP developed by staff and students of Stellenbosch University (InnovUS, 2010):

- A technological investigation to establish whether the IP can be registered;
- Estimating its commercial potential;
- Investigating the commercial and licensing possibilities;
- Undertaking the preliminary patenting of an invention;
- A preliminary market analysis, assisting with the establishment of a business plan, investigating of exploitation routes (whether through licensing, sale of rights, or the establishment of spin-off companies);
- Investigating sources of financing, the formation of partnerships and the finding of buyers;
- Negotiating business contracts with commercial partners;
- Protection, monitoring and providing on-going support for IP after contract conclusion with a partner;
- Managing relationships with commercial partners and the flow of revenue arising from commercial exploitation;
- Liaising with and reporting to the National Intellectual Property Management Office (NIMPO) and obtaining NIMPO approvals where required.

Many of the services described here relate to the many aspects of IP which have been described so far in this report. Patent searches, valuation, acquisition of IP rights, exploitation, monitoring and administrative work are all part of the portfolio at InnovUS. Apart from this, they are experienced and knowledgeable on the subject of IP and are a valuable asset to involve.

InnovUS will be involved with the IP outputs and have suggested contract agreements with the industrial partners who will be acquiring and using the technology developed. As mentioned earlier, the industrial partners will be acquiring the research outputs in return for their involvement in the research; however, this does not mean that they should allow this knowledge to leave the country. This is where the contract agreements will take effect. The industrial strategy is designed to allow South Africa to reap the full benefits of the research. The contracts should ensure that this is the case by preventing the technology from being used to form production plants in foreign countries with cheaper labour, and then exporting the raw materials to have the value added at a potentially lower base cost. Contracts should essentially be used to ensure that the IP is managed and exploited as desired by the government of South Africa.

The policy of Stellenbosch University states that "All staff should note that ownership of IP created by them in the normal course and scope of their duties and obligations vests in Stellenbosch University (University of Stellenbosch, 2010)." This is also the case for students who, during the course of their studies, develop IP at the university. The policy also prevents employees working closely with the technology from sharing that technology with possible future employers. This aspect could also be addressed with a confidentiality agreement that would need to be signed before one would be allowed to conduct the research in question.

4.2.3.2 Project Contracts and the IP Act

The Department of Science and Technology (DST) has contracted Stellenbosch University, through the Council for Scientific and Industrial Research (CSIR), to undertake the titanium machining research. Stellenbosch University has subsequently subcontracted the University of Cape Town, the University of Johannesburg and the German research organisation, Fraunhofer IWU. The contract network for both projects mentioned in this thesis, namely “High Performance Machining of Light Metals with an emphasis on titanium and selected alloys” as well as “Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications” are represented graphically in Figure 16 and 17. Note that the industrial partners, namely Aerosud, Daliff Precision Engineering as well as Southern Implants have committed themselves to the research as subcontractors to Stellenbosch University in the most recent project.

Local contracts are fairly simple to compile. However, when we consider international contracting, we need to consider the intellectual property rights from publically financed research and development act, 2008 (Act no. 51 of 2008) of which relevant sections can be found in Appendix 5. The objective of this act is described in section 2(1) as follows: “The object of this act is to make provision that intellectual property emanating from publicly financed research and development is identified, protected, utilised and commercialised for the benefit of the people of the Republic, whether it be for a social, economic, military or any other benefit”. It states that “intellectual property emanating from publicly financed research and development shall be owned by the recipient.” The recipient in this context is defined as “any person, juristic or non-juristic, that undertakes research and development using funding from a funding agency and includes an institution.” The recipients who would develop IP in this project are the Universities of South Africa as can be seen in the figure above. This means that any IP emanating from this research needs to be owned by them. Although this technically applies to all the subcontractors, the important factor here is that any IP remains within South Africa. Provision has been made to cater for this act in the contracts with both the University of Cape Town as well as the University of Johannesburg. As the primary contract holder, Stellenbosch University has an added management responsibility. This being the need to ensure that in the exploitation of all the IP generated from the main contract, including that generated by the subcontractors, the provisions of the IP act (Act no. 51 of 2008) are observed.

This can be found in section 10.2 of their respective contracts compiled for the project, “High Performance Machining of Light Metals with an emphasis on titanium and selected alloys” and reads as follows: “Any intellectual property emanating from the project shall be managed by the subcontractor in accordance with the provisions of the intellectual property rights from publicly financed research and development act, 2008 (Act no.51 of 2008).” One of the reasons for the rights remaining in the possession of Stellenbosch University, is to ensure that the IP be used in the way in which the government intended it to be when this project was drafted. The agreement section (2) of the Stellenbosch University – DST contract states that “In terms of the agreement the DST undertakes to pay the project funds to the recipient and the recipient undertakes to carry out the project in accordance with the terms and conditions contained herein.”

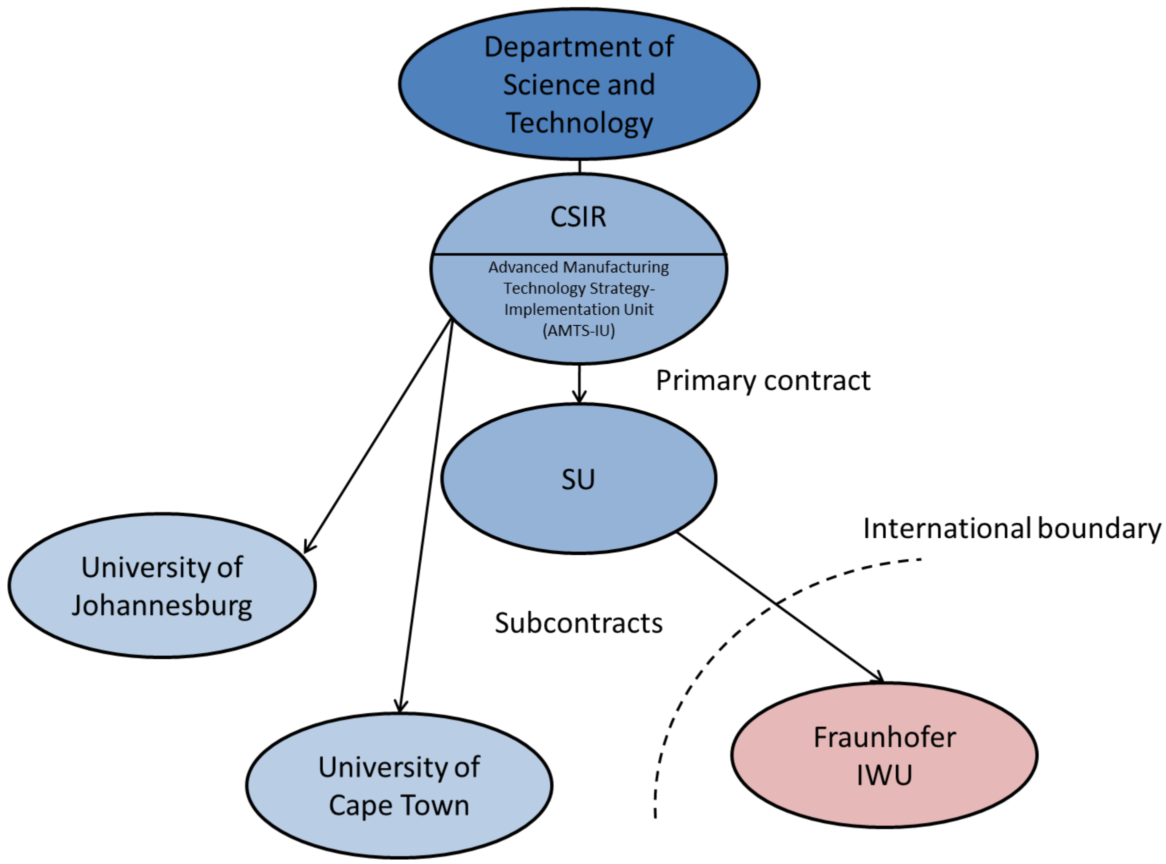

Figure 16: Titanium machining contract network (High Performance Machining of Light Metals)

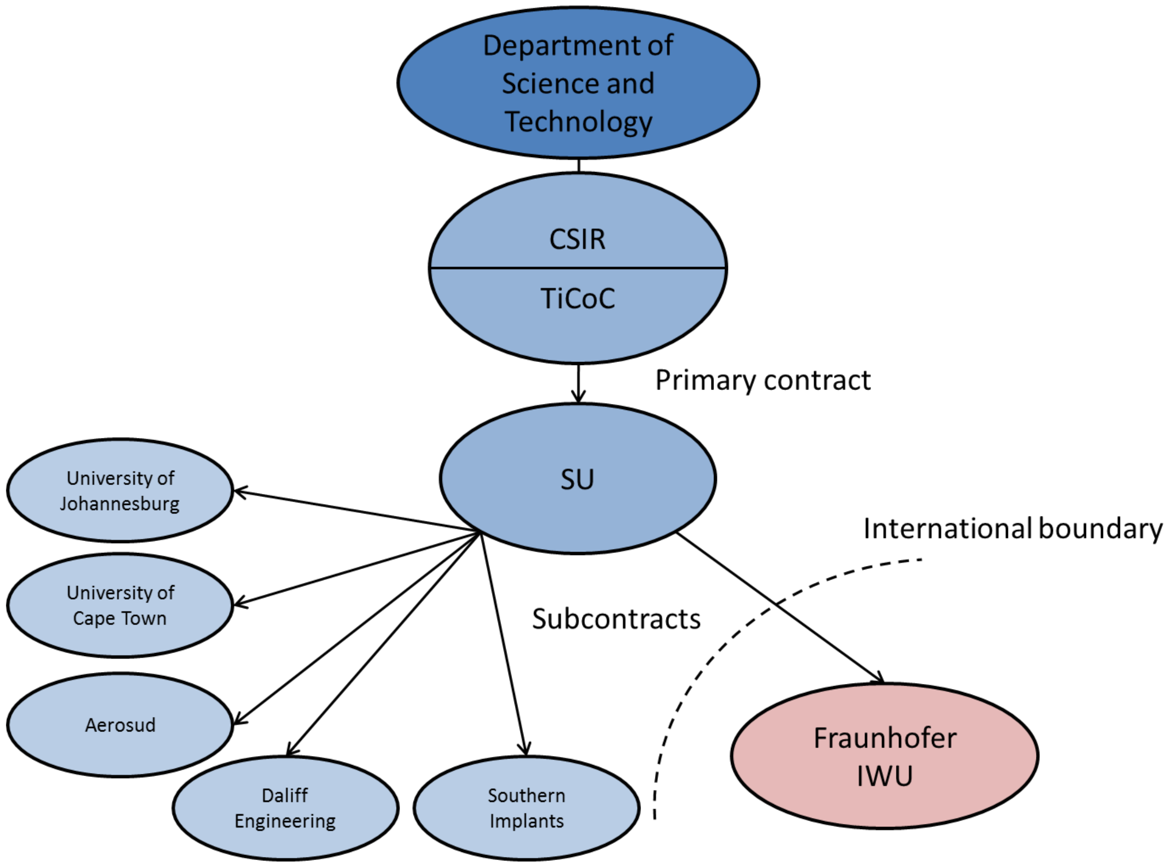

Figure 17: Titanium machining contract network (Resource Efficient Process Chains)

As far as the contract with Fraunhofer is concerned, all IP emanating from the research conducted for the project needs to be made available to Stellenbosch University through either exclusive, royalty free right of use or an exclusive royalty bearing right of use. The details of the rights of use section, found in the contract between Stellenbosch University and Fraunhofer for "High Performance Machining of Light Metals with an emphasis on titanium and selected alloys", are illustrated in the Figure 18.

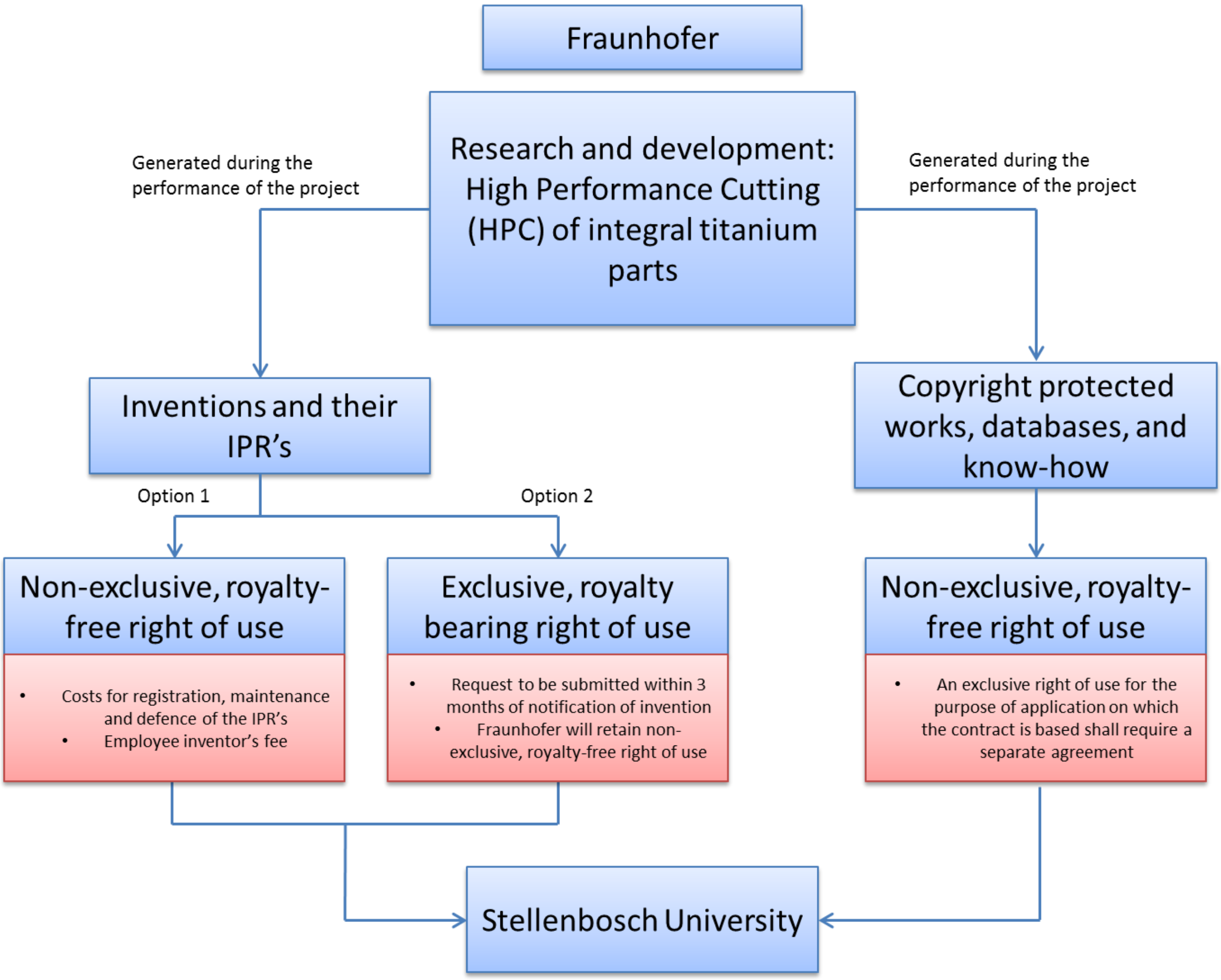

Figure 18: Visualised Fraunhofer contractual agreement

For any inventions and the IPR's filed by Fraunhofer which are generated during the performance of the project, two options exist to Stellenbosch University. The first option, which will always apply assuming that the second option is not chosen, grants a non-exclusive, royalty-free right of use for the purpose of application on which the contract is based to Stellenbosch University. This option requires that Fraunhofer be reimbursed an appropriate part of the costs for registration, maintenance and defence of the IPR's. This amount is to be agreed upon between the contracting parties. Additionally Stellenbosch University shall pay, in case of use of the inventions, a comprehensive employee inventor's fee, the amount of which shall be agreed in each individual case.

The second option requires that Stellenbosch University make a written request to Fraunhofer, informing them that an exclusive, royalty bearing right of use for the purpose of application on which the contract is based to inventions generated during the performance of the project (including the relevant IPR's) is desired. This request must be made no later than 3 months after the University's notification of the invention. Fraunhofer will retain a non-exclusive, royalty-free right of use for purposes of research and development.

As for any copyright protected works, databases, and know-how created during the performance of the project, Stellenbosch University shall be granted a non-exclusive, royalty-free right of use for the purpose of application on which the contract is based. The granting of an exclusive right of use for the purpose of application on which the contract is based shall require a separate agreement.

4.2.4 Summary

The localisation and retention of IP for the titanium machining research could essentially be handled in one of two ways, coupled with a good understanding of the basics of IP as well as effective management practices. The first way is that of licensing, which as described earlier in the chapter, can only occur with a registered IPR. In the case of the research being conducted into titanium machining, the licensing agreement will be unique in that the university will not receive any form of payment from the industrial partners, but will still retain control over the rights. This, of course, does not mean that there is no benefit for the University. Successful research and development, along with its transfer into industry, will serve to promote further investments into research and development projects.

The second way to ensure that IP is retained is related more to know-how. Essentially, an aspect of IP which either cannot be protected by an IPR or one which can be protected by an IPR, but a choice is made not to follow that route. To protect know-how, a combination of excellent contractual drafting and a certain level of secrecy need to be introduced. Essentially, the information needs to be handled as a kind of trade secret to ensure that the hard work which is being conducted, benefits the economy by empowering the titanium machining industry in South Africa.

No matter which of these two routes are followed, the starting point in the development of the IP strategy for titanium machining should be an in depth understanding of the project contracts. This means studying the project contracts and liaising with the universities IP professionals at InnovUS. It is also important to consider the policy of the university with regards to IP. The next step is to understand what options are available to protect the IP which will emanate from the research and development. A good understanding of the IPR's and how to register them is essential, not only to the people who will ultimately make the decisions, but also to the individuals developing the new technology. Potential IP can be compromised at a very early stage in its development if a proper understanding of how IPR's work is not in place. Once this knowledge is in place, the structure of the IP strategy can begin to take shape.

In order to implement an IP strategy for the titanium machining research, an IP portfolio which contains all of the IP owned by the university relating to the research must be compiled. Once the portfolio is complete, an IP audit can be conducted where important questions are answered about the IP. These questions help in determining what should be done with the IP going forward. Further management decisions can then be made based on the new information acquired.

An IP strategy overview is represented in Figure 19, which incorporates everything which has been described in this report with regards to IP. The aim is to show what is required in order to create a successful IP strategy, from the inputs which are described above and represented in red, to the internal (blue) and external (green) considerations which define the strategy. Each block in this structure includes the chapter number of that section where further information can be found.

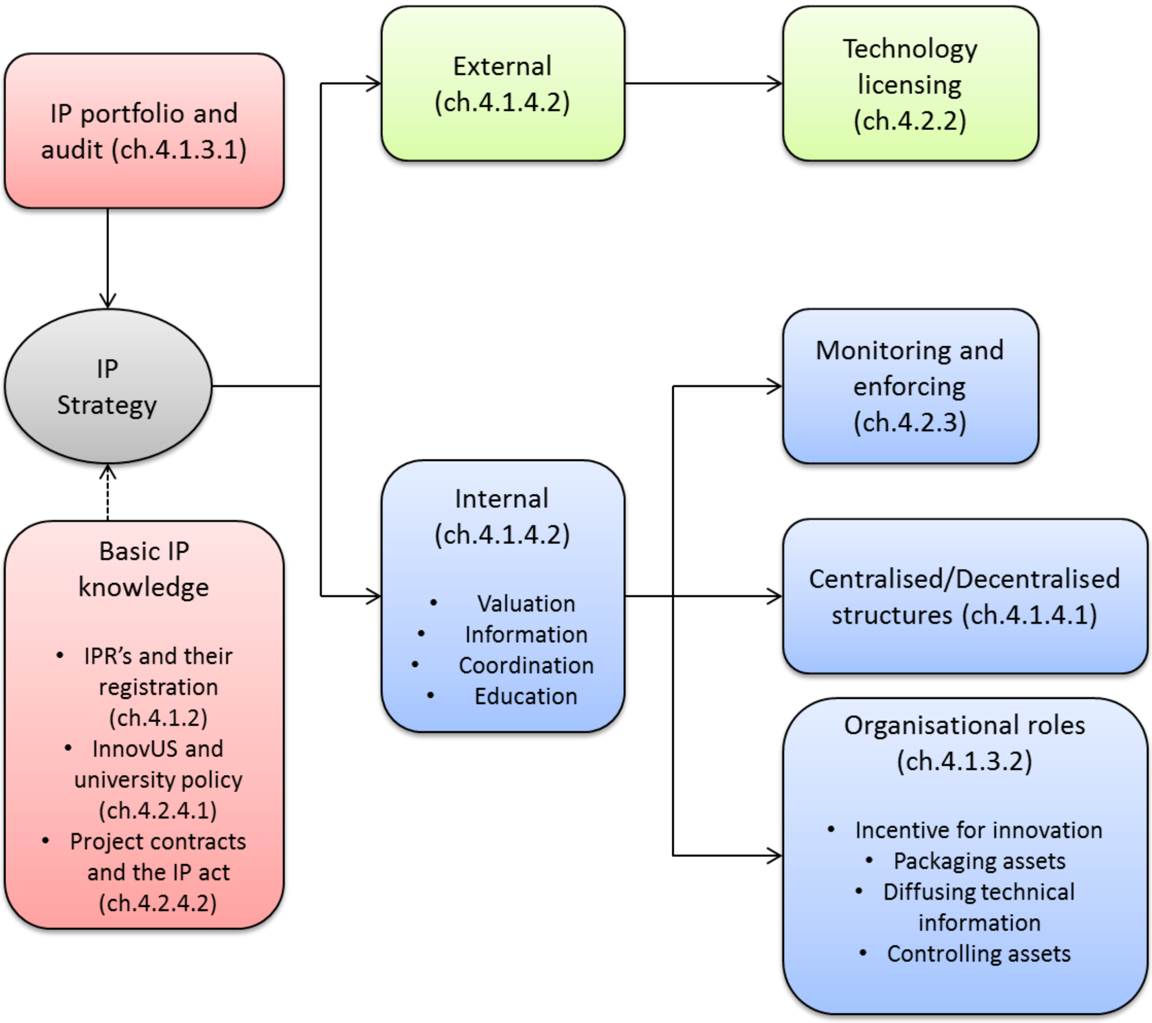

Figure 19: IP strategy overview

4.3 Plan for IP Outputs and Patentability

In this section a step by step plan for the protection of IP which emanates from the titanium machining research is presented. What this will do is to describe what the process of protection might play out once protectable IP is created. Ideally an IP portfolio will be created once the reports on the work described by the research inputs mentioned, have been completed. Although these steps are briefly described here, many of them have been explained in more detail already. Patentability will also be considered with an example showing what kind of questions need to be answered in order to determine whether or not an innovation is patentable or not.

4.3.1 Plan for IP Output

The following plan for IP outputs for the titanium machining research begins with some practices which should be incorporated into any research and development being done, regardless of whether or not any protectable IP will arise. These initial steps need to be carried out by the researchers in order to facilitate the protection of any IP which may arise.

1. Familiarise oneself with the basics of IP and be aware of some of the existing pitfalls which might obstruct the process of IP protection. A basic understanding can be gained through the study of this report or even a visit to InnovUS where any questions one might have with regards to IP will be answered.
2. Date and document all work which is being undertaken. As explained earlier, proper documentation will support ones application for IP protection and can be a form of protection in itself as copyright material.
3. If any researcher feels that the research which they are conducting is creating valuable IP, they should liaise with InnovUS who will be able to guide them further. The first thing which InnovUS will have a researcher do is to fill out a disclosure form. This form can be found in Appendix 6 and is described in further detail at a later stage in this chapter.

It is from this point onwards, assuming that some valuable IP has arisen, that InnovUS would take a more active role and attempt to acquire the protection which is most suitable for the particular case at hand. This does not mean that the researchers should cease any involvement with the protection of the IP, but instead should work alongside InnovUS by providing further insight into the work which they have conducted. The following steps describe this process.

4. Determine how to approach IP protection for the given case. Is the IP patentable or will it be handled as know-how and protected as such?
5. Once the IP has been identified and an approach for its protection determined a technological investigation can be conducted. This includes:
   - Establish whether or not the IP is registerable;
   - Estimating the IP's commercial potential;
   - Undertaking the preliminary patenting of an invention.
6. Negotiation of business contracts with industrial partners. This step will require input from all the parties involved with the project including the project team (researchers and project leaders) as well as the investors.
7. Protection, monitoring and providing on-going support for IP after contract conclusion with an industrial partner.

4.3.2 Patentability and the Policy of InnovUS

The following information can be found in part 3, procedures for the protection and commercial exploitation of intellectual property, of the policy of InnovUS (InnovUS, 2010). As stated in the policy of InnovUS, the novelty requirement is of particular importance for patents and design rights and any inventor with an idea must first test it against the current state of the art. The current state of the art includes all publications on and uses of similar products, processes and methods, and especially in the relevant field of application. The policy also states that it is the inventor who is obliged to ensure at all times that the invention is kept confidential noting that early publication or public use can destroy the possibility for a patent and that the novelty requirement is vitiated if this happens.

With regards to the disclosure of IP, the policy states that in order to ensure maximum utilisation of new IP, identification and disclosure thereof must be made to InnovUS as soon as possible that a new and potentially useful product, process, method or design has been conceptualised. It should also be noted that IP created using public funds, as would be the case with the titanium machining research, that is not disclosed to NIPMO may be claimed by NIPMO as of the terms of the 2008 IP Act. It is thus imperative that early disclosure of all new IP be made to InnovUS so as to enable InnovUS to report such new IP to NIPMO. Since public disclosure vitiates the possibility of patenting, publication of research results must be held back until such a time as SU authorises such publication.

Ultimately InnovUS has the final say in the decision to register, or not register a patent for a particular invention or model of which the ownership vests in Stellenbosch University. InnovUS shall endeavour to take a decision regarding the seeking of provisional protection within three months of disclosure thereof. In the case where InnovUS decides not to register a patent for publicly funded IP in respect of which it owns the right, as is the case for the titanium machining research, Stellenbosch University is required by law to notify NIPMO of such a decision and provide reasons for the decision at which point NIPMO may elect to acquire ownership of the IP.

4.3.3 InnovUS Disclosure Form

One of the first things which will be required of a researcher, once they have notified InnovUS of a possible innovation, will be to fill out a disclosure form. The disclosure form can be found in Appendix 6 and has been completed by a PhD engineering student, Mr Pieter Conradie, who is busy conducting research for titanium machining. He is in the process of developing a cost model for titanium machining in industry applications amongst other research. The disclosure form was completed by him specifically for his work on the cost model and is to be used as an example in this section to determine what course of action could be taken in order to protect this potential IP asset.

The disclosure form begins with the name of the innovation before some background is determined. Question 2 specifically inquires as to whether or not the inventor has any knowledge with regards to any similar technologies which might exist. This of course is to determine whether or not the innovation is new, that is, it does not form part of the state of the art immediately before the priority date of the invention. Although these questions only tell of any technologies of which the inventor is aware of, InnovUS will still conduct a technological investigation to establish whether or not the IP can be registered. In this case Mr Conradie explains that many other cost models do exist, however, they are not specifically related to the milling operations of titanium as is the one which he is developing. He also mentions that his model is significantly simpler as opposed to the rather complex generic ones which are available.

The next set of questions is all about the innovation itself. Firstly the type of innovation and its field of study are determined. A short description is then required followed by information regarding any problems which the new technology might solve as well as any other benefits it provides. This information provides insight as to what makes the invention unique and possibly patentable. The origins of the innovation are then questioned as well as whether or not it has been disclosed to any parties other than InnovUS. In the case of the of the cost model, Mr Conradie identifies it as a procedural innovation of the engineering field and then proceeds to explain that the cost model aims to approximate cost associated with machining a titanium part on a specific machine setup. The problem solved by this model is that it is specifically for titanium milling operations, of which a cost model is yet to exist. The simplification of the cost model as well as its user friendliness is described under benefits. The origin of the cost model is described to be as a result of the titanium machining research initiative and a lack of means to determine costs once this kind of technology was transferred to industry. Mr Conradie notes that the idea has not been disclosed thus far. This is essential if a patent application is to be filed as it means that the innovation can still be considered new.

The next few questions focus on the development status of the innovation. Whether a working prototype/test results exist as well as whether or not the technology can be demonstrated is determined. Essentially these questions identify how complete the new technology is. It is important to note that the technology does not have to be fully completed to justify a provisional patent application. The provisional period associated with patent applications allows time for amendments to be made to the innovation. It is important to note that if any significant changes are made to the technology, a new provisional patent must be taken to protect the new information. Mr Conradie notes that the cost model is still under development and that once it is completed, it will be used in the titanium machining industry in South Africa.

The final few questions are with regards to the research contract, the financer as well as personal and employment details of the inventor. Once completed this disclosure form will enable the University to support the initiative of the party concerned and to ensure that all possible IPR's (including expertise) are sufficiently protected on behalf of both the individual and the University.

4.3.4 Summary

Although the requirements for patentability are very clear (new, useful and non-obvious), the decision to apply for one might not be that simple. A decision needs to be made with every piece of potential IP that is generated during the titanium machining research initiative. Sometimes publication might not be the best course of action. Instead, it might be preferable to treat the new IP as a trade secret. The technology packs, described in the plan for research input in the previous chapter, package all the potential IP neatly and could be treated as trade secrets. The question of a new technologies commercial viability might also influence whether or not a patent application should be filed. There needs to be a demand for the technology as well as the potential to make a profit. One needs to ask if the potential benefits of filing for a patent outweigh the effort, expense as well as the risk which is involved. A provisional patent application is almost always a safe bet, allowing at least a year's time to decide whether or not to proceed with the patenting process. By filing a provisional patent one also creates a filing date and lays claim to the innovation. Any applications filed after said date cannot infringe upon the content of the original application.

For the research into titanium machining this chapter provides guidelines and examples both to analyse whether or not IP is patentable as well as the steps which need to be taken in order to go about actually acquiring a patent. It is difficult to predict the patentability of technologies which are not yet completed. Each innovation which arises as a result of the research initiative for titanium machining will have different answers to the questions asked in the InnovUS disclosure form and as such a decision as to how to protect them needs to be taken independently. Let us consider the cost model which was used in this chapter as an example. Although it appears that the cost model can be patented if so desired, it does not necessarily need to be in order to be an effective tool in the South African titanium machining industry. By simply transferring the cost model as a tool along with other such research to the industrial partners we are empowering the titanium machining industry in the country with the ability to predict cost associated with machining a titanium part on a specific machine setup. Internationally, most countries who machine titanium successfully and whom South Africa hopes one day to compete with are already aware of the costs of the titanium machining operations. As such, they would not need to make use of such a tool. However, there are other ways to protect IP like this, such as confidentiality agreements with the industrial partners and the treating of the IP as a trade secret. There are decisions which need to be made if the path of secrecy is chosen, keeping in mind that the research cannot be published in order to maintain said secrecy.

Chapter 5. Technology Transfer Strategy Implementation

In this chapter the industrial partners are described and the technology transfer strategy developed is validated. Validation for the technology transfer strategy is conducted through both a review of the implementations conducted at industrial partners to date as well as the planning of pilot implementations for the work presented in Work Package 1 of the project entitled "Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications".

5.1 Industrial Partners

The industrial partners for the titanium machining industrial strategy are Aerosud, Daliff Precision Engineering and Southern Implants. Much of the industrial partner descriptions can also be found in the titanium project, "Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications". These South African companies are leading the trend for titanium usage in their business operations and their participation ensures that the research work is aligned with the needs of the industry. They also provide the research and development with an initial route for transfer and industrial implementation of the developed technologies and competencies.

5.1.1 Aerosud

Aerosud is an established leader in the aviation industry supplying integrated manufacturing solutions. Aerosud is a smart supplier, capable of adding value to partnerships involving programme management, design, development and production processes (Aerosud, 2014). Aerosud has a proven capability with aluminium machining and is currently supplying machined structural components to Airbus, mainly on the A400M programme. Aerosud is also heavily involved with the new A350 programme where carbon composite frame-clips are being developed for the prototype aircraft. There is scope for immediate local content in terms of Titanium machining if the capability can be industrialised from laboratory environments to aircraft certified manufacturing facilities. Raw material will be imported for the first few years, however, when the technology is married with the primary beneficiation of local titanium deposits, the economic argument will become very strong and substantial manufacturing contracts will follow. Aerosud will be perfectly positioned with a long standing development and trade relationship with Airbus and Boeing and also the capability to supply the two most relevant structural technologies for all new aircraft. From a company point of view, the rapid maturing of this technology is of cardinal importance for securing future airframe structural contracts (Dimitrov & Damm, 2013).

5.1.2 Daliff Precision Engineering

Established in 1972, Daliff Precision Engineering have become known as one of the leaders in the field of machined components for the aerospace, avitronics/electronics and defence industries within South Africa (Daliff Precision Engineering, 2012). Daliff Precision Engineering is a supplier of high value added machined components to the advanced equipment, i.e. aircraft, defence (missiles, electronic warfare, radar, etc.), nuclear and medical industries. Current industry projections for titanium indicate a 40 per cent increase in demand by 2015 in Aerospace. Anticipating this growth, many major producers of titanium have announced plans to increase their production capacities. The same trends are foreseen for the other industries, in which Daliff operates. To be competitive in these markets, a lot of effort and energy has to be directed towards the improvement of machining processes for Titanium (Dimitrov & Damm, 2013).

5.1.3 Southern Implants

Southern Implants was established in 1987 to develop, manufacture and distribute dental implants. Southern Implants has been a pioneer in this field over the last two decades and has contributed extensively to on-going enhancements with respect to osseointegration of implant devices, surgical techniques, patient education and options for treatment (Southern Implants, 2012). The dental implant market worldwide is estimated at 2 billion Euros, growing to 4 billion Euros by 2025. At least 85% of this is titanium products (titanium implants, titanium abutments and titanium superstructures). Southern Implants has just over 1% market share globally, but in countries like South Africa and Chile, they are the market leaders with over 40% market share. In the past 2 years, the global market leaders, Nobelbiocare and Straumann, have grown at less than 4% whereas in North America Southern Implants has achieved in excess of 40% growth, making them the fastest growing implant company (Dimitrov & Damm, 2013).

5.2 Technology Implementations at Aerosud

Two implementations have been conducted at the industrial partner, Aerosud to date. The first was in 2013 and consisted of straight line cut tests at different cutting speeds in order to compare the tool wear data obtained at Stellenbosch University to that obtained at Aerosud. This initial implementation also served as a research opportunity, allowing those involved to gain an understanding of the environment at one of the industrial partners. The details of this implementation are available in the technical report entitled “Approach for Cutting Strategies Evaluation and Selection” prepared for the project, “High Performance Machining of Light Metals with an emphasis on titanium and selected alloys” (Dimitrov, et al., 2013). The computer numerical control (CNC) machines as well as computer aided design (CAD)/computer aided manufacturing (CAM) software used at Stellenbosch University and Aerosud are not the same. Stellenbosch University conducted its tests on the Hermle C40U dynamic machine using Powermill CAM software, while at Aerosud machining was conducted on DMU machine where they usually use CATIA CAD software and post-process with VERICUT in order to run it on their machines. In the case of the tests conducted however, the Powermill files used in the cuts at Stellenbosch University were post-processed with VERICUT and run on the DMU at Aerosud.

Let us now consider the technology transfer model developed and expand upon the elements represented therein and how they translate into this particular implementation. This is shown in Table 6.

Table 6: Technology transfer elements for straight line cuts

Technology transfer elements	Translation into the implementation
Transferor	Stellenbosch University
Transfer environment	• CNC machine: Hermle C40U dynamic ○ Cooling: Flood cooling – 3 sides ○ Through spindle cooling pressure: 55 BAR ○ Work piece clamping: Vice direct on table clamping block ○ Z axis movement: In spindle ○ Tool holders: NT tool clamping system • CAD/CAM software: Powermill
Technology	Straight line cut tests (Tool wear analysis)
Transferee	Aerosud
Transfer environment	• CNC machine: DMU ○ Cooling: Flood cooling – 2 sides ○ Through spindle cooling pressure: 20 BAR ○ Work piece clamping: Vice mounted on pedestal, mounted on table ○ Z axis movement: In table ○ Tool holders: Iscar shrink fit • CAD/CAM software: Usually CATIA with VERICUT post-processing, however, Powermill files post-processed with VERICUT for this experiment
Transfer mechanism	Implementation of tests at industrial partner for comparison

The tests were conducted at cutting speeds of both 80m/min and 120m/min and the results are illustrated in Figure 20 and 21.

The results show that the wear tendencies for both machines are very similar. It is clear however, that the DMU of Aerosud outperforms the Hermle machine at Stellenbosch University slightly. To conclude, the results and feedback gained from tests are analysed as per the technology transfer model.

For this particular technology transfer scenario, the effectiveness criteria of market impact and economic development are not relevant as the transfer was intended to gain an insight into the environment of the industrial partner and confirm that research into titanium machining can in fact be successfully implemented into industry. The project goals are therefore the criteria to consider in this case, being to determine whether the process and results achieved in the laboratory at Stellenbosch University can be duplicated in a typical industrial environment. This effectiveness criteria is analysed through the results obtained as well as the feedback gained by the implementation of this research into industry.

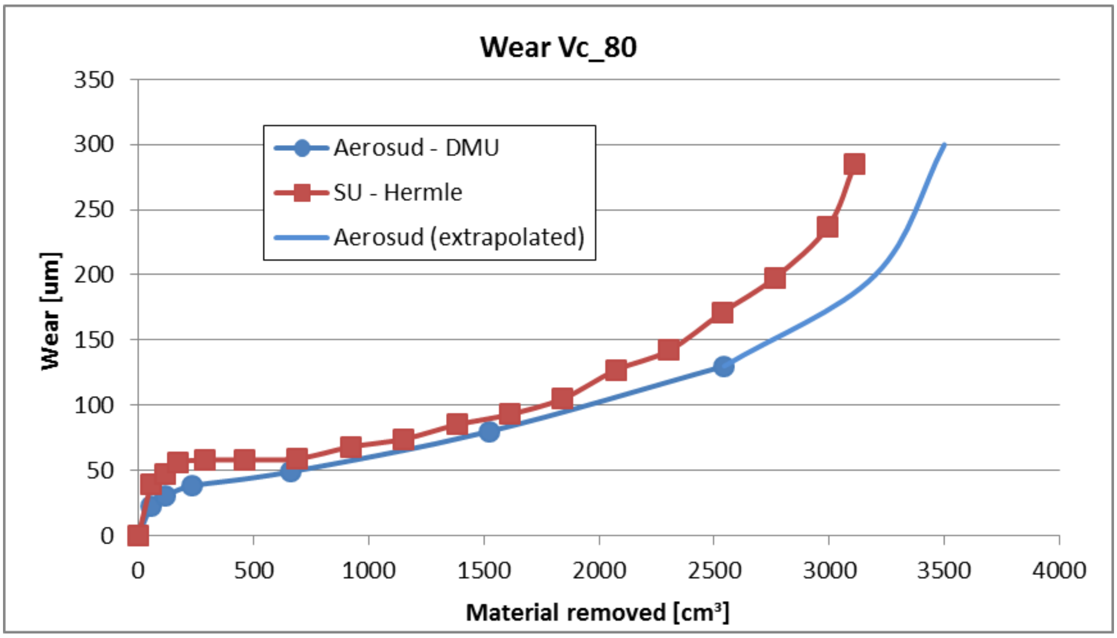

Figure 20: Wear results for cutting speed: 80m/min (Dimitrov, et al., 2013)

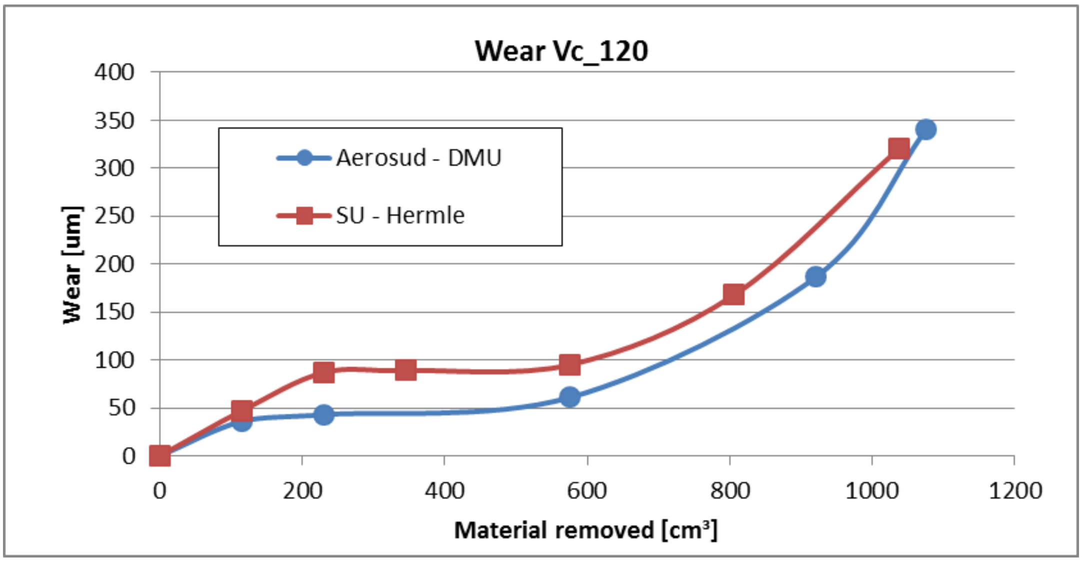

Figure 21: Wear results for cutting speed: 120m/min (Dimitrov, et al., 2013)

The difference in tool wear between the two tests, although very similar, requires the some consideration. Some of the aspects identified as to the differences between the results and identified in the technical report "Approach for Cutting Strategies Evaluation and Selection" include:

- The state of the spindles of the two machines:
  - Aerosud had replaced the spindle on the DMU three days before the experiments were conducted, and as a result vibrations from the spindle would be an absolute minimum and accuracy would be very precise.
  - The spindle on the Hermle had not yet been replaced and it is noted that it had suffered two collisions in the months leading up to the experiments.

- The size of the machine and table:
  - It was noted that another reason for lower cutting forces and vibrations observed on the DMU could have been due to the larger size of the machine as well as its table upon which the pedestal which held the part, was clamped.

Overall the conclusion made is extremely positive as the wear tendencies corresponded well between the experiment conducted at Stellenbosch University and the one conducted at Aerosud. This proved that machining operations performed can be repeated on different machines and in different environments. This experiment provides positive reinforcement to the goal of the technology transfer strategy by showing that transference of research being conducted for the titanium machining industry is possible.

The second of these implementations focused on different machining strategies and cutting conditions and was carried out through the machining of a structural aerospace part from the product range of Aerosud, the Intercostal, illustrated in Figure 22.

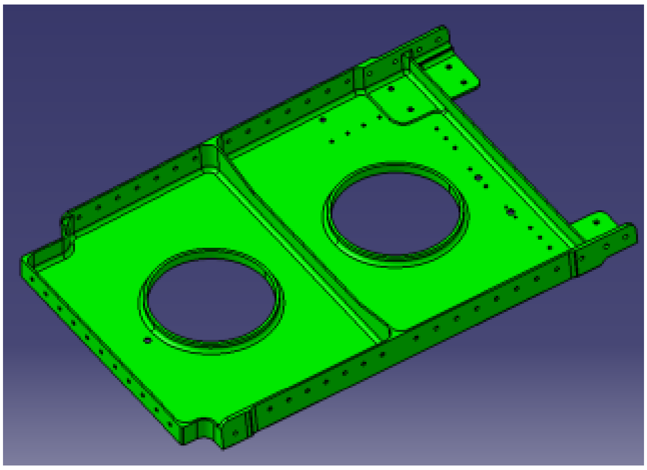

Figure 22: Intercostal

The details of this pilot implementation are available in the progress report prepared for the project, “Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications” (Dimitrov, et al., 2014). The main goal of the experiment to machine such a complex part out of titanium was to test the efficiency of the CATIA software which Aerosud uses as well as that of Powermill which was used at Stellenbosch University to machine the same part.

Let us now consider the technology transfer model developed and expand upon the elements represented therein and how they translate into this particular pilot implementation. This is shown in Table 7.

Both Stellenbosch University as well as Aerosud were able to successfully machine the part in question; however, the main focus was on the cutting strategies used and their respective software packages. The progress report states in its description of the cutting strategy used at Stellenbosch that “With the research that has been done on the machining of titanium alloys, it was found that the best tool life is obtained when a cutting strategy is used that maintains a constant engagement angle during a cutting operation regardless of the geometry of the part. This is possible with a cutting strategy that creates tool paths in such a manner that recurring slicing motions of different trochoidal radii are used to conform to the geometric feature of the part. A strategy that conforms to these requirements is the Vortex cutting strategy within the Powermill software package from Delcam." As a result of this choice in cutting strategy the report concludes that "All the tool paths discussed were machined without problems and the observable cutting conditions such as spindle load, cutting noise and vibration were constantly low which was a good indication that the cutting strategy performed well."

Table 7: Technology transfer elements for the machining of the Intercostal

Technology transfer elements	Translation into the implementation
Transferor	Stellenbosch University
Transfer environment	• CNC machine: Hermle C40U dynamic ○ Cooling: Flood cooling – 3 sides ○ Through spindle cooling pressure: 55 BAR ○ Work piece clamping: Vice direct on table clamping block ○ Z axis movement: In spindle ○ Tool holders: NT tool clamping system • CAD/CAM software: Powermill
Technology	Cutting strategies for the machining of the Intercostal demonstrator part
Transferee	Aerosud
Transfer environment	• CNC machine: DMU ○ Cooling: Flood cooling – 2 sides ○ Through spindle cooling pressure: 20 BAR ○ Work piece clamping: Vice mounted on pedestal, mounted on table ○ Z axis movement: In table ○ Tool holders: Iscar shrink fit • CAD/CAM software: Usually CATIA with VERICUT post-processing, however, Powermill files post-processed with VERICUT for this experiment
Transfer mechanism	Pilot implementation at Aerosud

When the same part was machined at Aerosud, the CATIA software was used. Initially there were problems with the cutting strategies being used resulting in "overloads on the tool and ultimately failure." The progress report states that at this stage in the operations "It became clear that the available strategies in the CATIA software were not so well suited for machining of titanium as it was not possible to obtain tool paths that gave positive results with the simulations." After a suitable strategy failed to be found, an approach using simple straight line trochoidal machining was proposed. The report states in relation to this proposal that "Although this is not an optimized tool path, as it is very time consuming to machine in this manner, it was chosen to simply test if there was a strategy that could be implemented successfully on the CATIA software." After all the outside sections were machined using the trochoidal cutting strategy, the wear on the cutting edges was seen to be relatively low. It was at this stage with some research into the CATIA software that a later release version of CATIA was found. Hereafter the progress report states that the newer version of CATIA had "much more functionality in creating tool paths where the tool was not overloaded." It also states that "A tool path strategy called 'adaptive concentric milling' proved to be very promising when the tool path simulations were run on the software. This strategy had similar features to Vortex by maintaining a constant stepover and constant load on the tool." Once this strategy was initiated the simulations gave very promising results. Ultimately the new cutting strategy proved to be very efficient and the scenario highlighted the importance of using the latest version and software service packs.

The effectiveness criteria of the technology transfer model as well as the feedback gained can now be analysed with respect to this implementation. Although market impact and economic development were not measured in the case of this implementation, the fact that the software at Aerosud was updated as a result of the problems observed while machining the Intercostal could very well have improved the efficiency of their standard machining procedures. As far as project goals are concerned, the aim of successfully and efficiently machining the complex aerospace demonstrator part was achieved. The feedback with regards to the updating of CAM software is summarised neatly by the progress report which states that "with the continuous research and development in CAM software, significant improvements are made with regards to cutting strategies. This was illustrated with the use of both the Powermill and the CATIA software packages. With both these CAM packages, significant advancements were made in a period of two to three release versions. The industry is not always aware of this fact, but it is very important that companies always make use of the latest releases or updates within their CAM departments."

An important observation to make is to note how the market impact and economic development effectiveness criteria are not relevant in the technology transfer implementations described here. This is because both of these scenarios was conducted in order to gain an insight into the industrial partner work environment as well as determine whether or not the research conducted at Stellenbosch could in fact be replicated at an industrial partner. It is for this reason that the project goals as well as the quality of the feedback gained are more relevant to determine the success of these technology transfer implementations. Ultimately however, market impact and economic development are extremely important effectiveness criteria in order to determine the success of the transfer of the finished technologies and the titanium machining industrial strategy as a whole.

Overall the technology transfer implementations:

- Identified know-how developed in Stellenbosch University as such (Important for IP protection strategies to be developed)
- Tested whether the know-how could be applied (via replication) at the industrial partner
- Showed that the transfer of know-how occurs more effectively through people rather than just documents

5.3 Plans for Future Technology Transfer

Now that a model for technology transfer has been developed, the transfer of the technologies being developed in Work Package 1 can be expanded upon. The initial transfer of technology from this work package will be through pilot implementations. These will be conducted in collaboration with the industrial partners. Each of the 5 processes/process combinations described at the beginning of chapter 3 in the plan for research input, are linked to one of the industrial partners most relevant to them. The details of these pilot implementations can be seen in the technology – industrial partner linkage map in Figure 23, which is a more detailed version of the industrial partner/research institute linkage map which can be found in Appendix 2. It provides images of the demonstrator parts being used as well as information regarding the assessment of the pilot implementations.

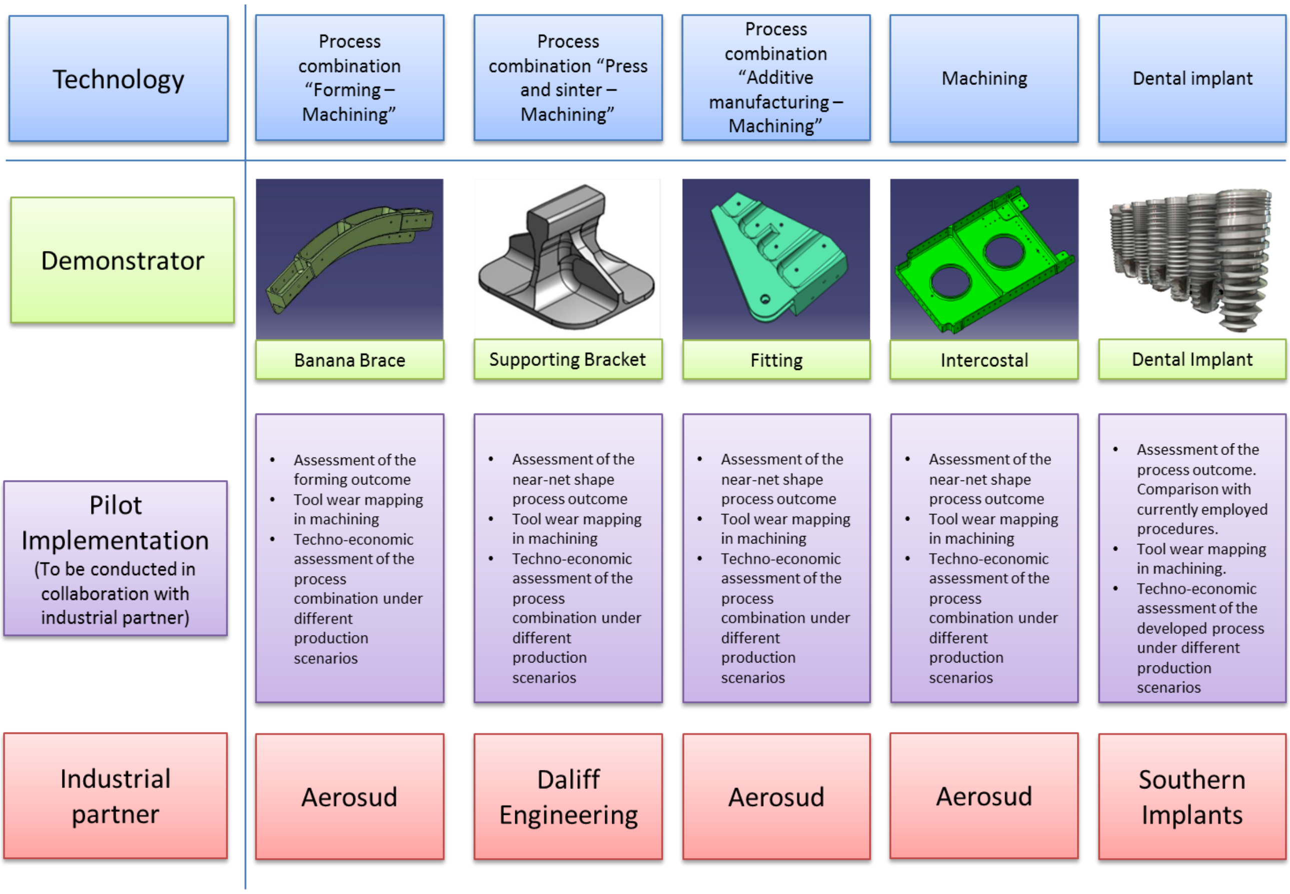

Figure 23: Technology - Industrial partner linkage map

The six elements of the technology transfer model are now considered once again, however, they can now be matched to the processes/process combinations of the linkage map to provide an example of an actual technology transfer scenario. Table 8 shows this, using the process combination "Additive manufacturing – Machining" as an example, along with some consideration for other aspects of the technology transfer model.

The technology transfer mechanism for Work Package 1 consists of multiple pilot implementations, which allows for the validation of the technology/competencies before full application deployment. It is for this reason that the feedback from such implementations is so important, informing the researchers at the universities where any problems might lie and therefore where to focus future research.

A pilot implementation is a great initial transfer mechanism, and if successful, can be followed up with licensing agreements, if protectable IP exists, as well as support contracts in which Stellenbosch University would participate in the technology implementation, providing support at each stage of the transfer. It is extremely important that an in depth techno-economic analysis is performed in order to address the effectiveness criteria of market impact as well as economic development.

Table 8: Technology transfer elements for pilot implementation

Technology transfer elements	Example
Transferor **(Transfer environment)**	Stellenbosch University (Physical and organisational infrastructure, personnel, resources)
Technology **(Demonstrator part)**	Additive manufacturing – Machining (Fitting)
Transferee **(Transfer environment)**	Aerosud (Physical and organisational infrastructure, skills availability, technological status)
Transfer mechanism	Pilot implementation at the industrial partner
Feedback **(Effectiveness criteria)**	• Project goals assessed via near net-shape process outcome as well as tool wear mapping. • Economic factors assessed via a techno-economic analysis of the process combination under different production scenarios.

Chapter 6. Outcomes Plan for the Technology Transfer and IP Strategies Developed for Titanium Machining

For this outcomes plan, how the strategies developed for the titanium machining research initiative should be used for predicted scenarios is explored, as well as what the potential outcomes of those scenarios might be. The benefits for each of the parties involved in the research initiative are particularly important to consider.

6.1 Analysis of Potential Inputs/Outputs of the titanium machining research

The technology transfer and IP strategies are represented in Figure 24, below as simple flow diagrams. Although they are not necessarily as simple as depicted, the focus here is on the IP and technologies being created via the titanium machining research initiative. The IP strategy for example, includes information on the management of IP, its organizational roles and describes different structures which can be adopted. Here however, we simply focus on the inputs and potential outputs which the titanium machining project might produce and analyse what the benefits might be for the different parties involved.

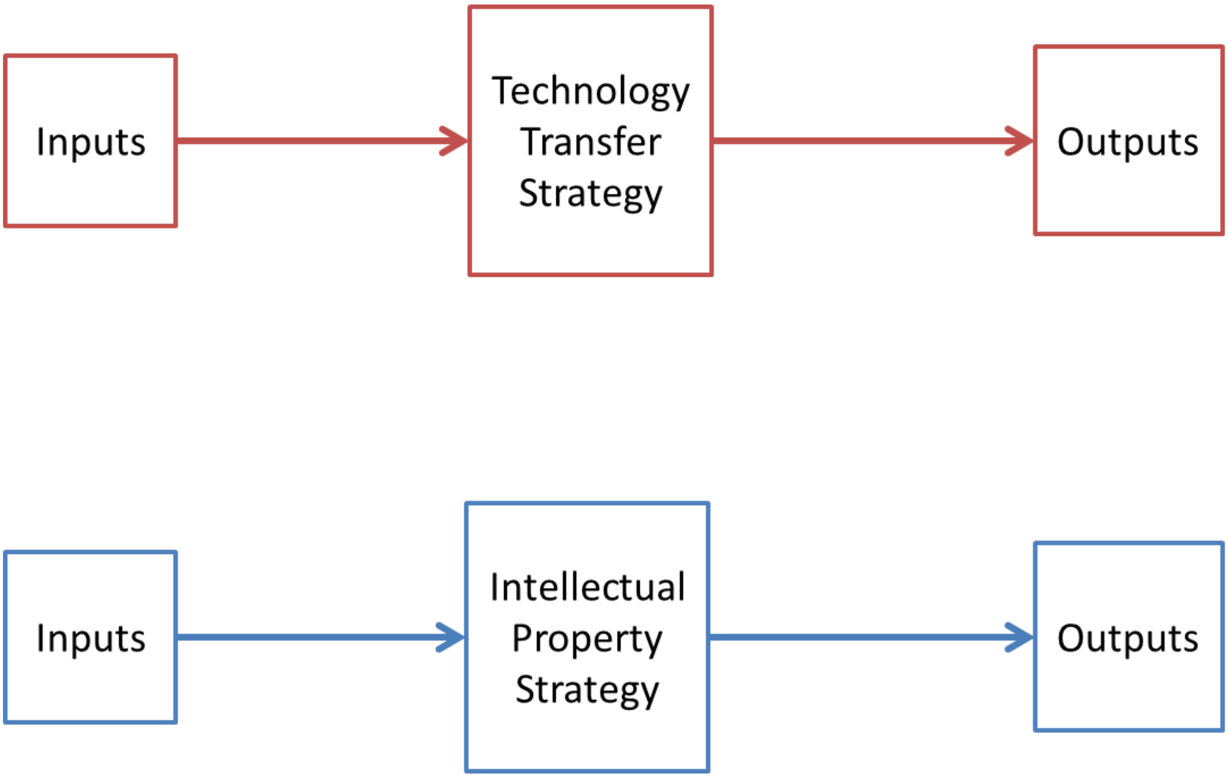

Figure 24: Simple flow diagrams for technology transfer and IP strategies

Let us first consider the inputs represented in Figure 24, and consider what these might be for the titanium machining project. As mentioned in this thesis, new developments which arise as a result of this research undertaking will most likely be either a new technological invention or some new form of know-how. These are relevant inputs for both the technology transfer and IP strategies and will be used as such. An additional input which can be added to the technology transfer strategies flow diagram is information. What this represents are the cases where, instead of an innovation being transferred from University to Industry, information is gathered through the implementation of research results at an industrial partner. This could be for the purposes of validation of certain results, comparison of results between University and industrial partner, or in order to gain insight and feedback from industrial partners into a particular research area.

The potential outputs for the inputs mentioned are represented in Table 9 along with a short description of each.

Table 9: Inputs and potential outputs for technology transfer and IP strategies

Inputs	Outputs	
	Technology transfer	**IP**
New technological invention	Physical implementation into industry	Patent (or other IPR) and accompanying licensing agreement
New form of know-how	Implementation into industry through knowledge sharing and demonstration	Trade Secret and accompanying contractual agreements
Information	Feedback and input from industrial partners, used to further research	-

As far as the IP outputs are concerned, deciding on whether to file for a patent or to treat the innovation as a trade secret is again more complicated than just matching a new invention to an IPR and some new know-how to a trade secret. This is however the most likely route one would follow in these scenarios.

A quick recap of patents as well as trade secrets as well as the types of technologies/knowledge which they might protect is shown in Table 10; these are covered in greater detail in this thesis.

Table 10: Patent/trade secret recap

Method of IP protection	Description	Examples
Patent	Exclusive legal right, granted for an invention. An IPR such as a patent is required to transfer IP via licensing agreements. • Last for 20 years • Patent co-operation treaty (PCT) option available to South Africa	• An invention which is novel and non-obvious
Trade Secret	A commercially valuable piece of information which is kept confidential. Value of information is entirely based on it being kept a secret. • Last for an indefinite amount of time • No registration or renewal fees • Effective immediately	• Unpublished research reports • Computer software • Production processes • Know-how

For the research planned for titanium machining, most of the outputs will most probably be in the form of one of the examples mentioned that are suitable for protection by means of a trade secret. This is because the focus of the research is on the development of different production processes as well as ways in which to make current machining practices more suitable and efficient for machining titanium.

As stressed in this thesis, each new development which is made through the research into titanium machining needs to be considered individually for the purposes of IP protection. Figure 25 summarises some of the questions and options one would need to consider when making such a decision. One of the first steps in protecting ones IP is to determine whether or not it has in fact been protected already. If any IP infringements exist and the technology in question has already been patented for example, one might consider licensing in the rights if that technology is crucial to furthering the research being conducted.

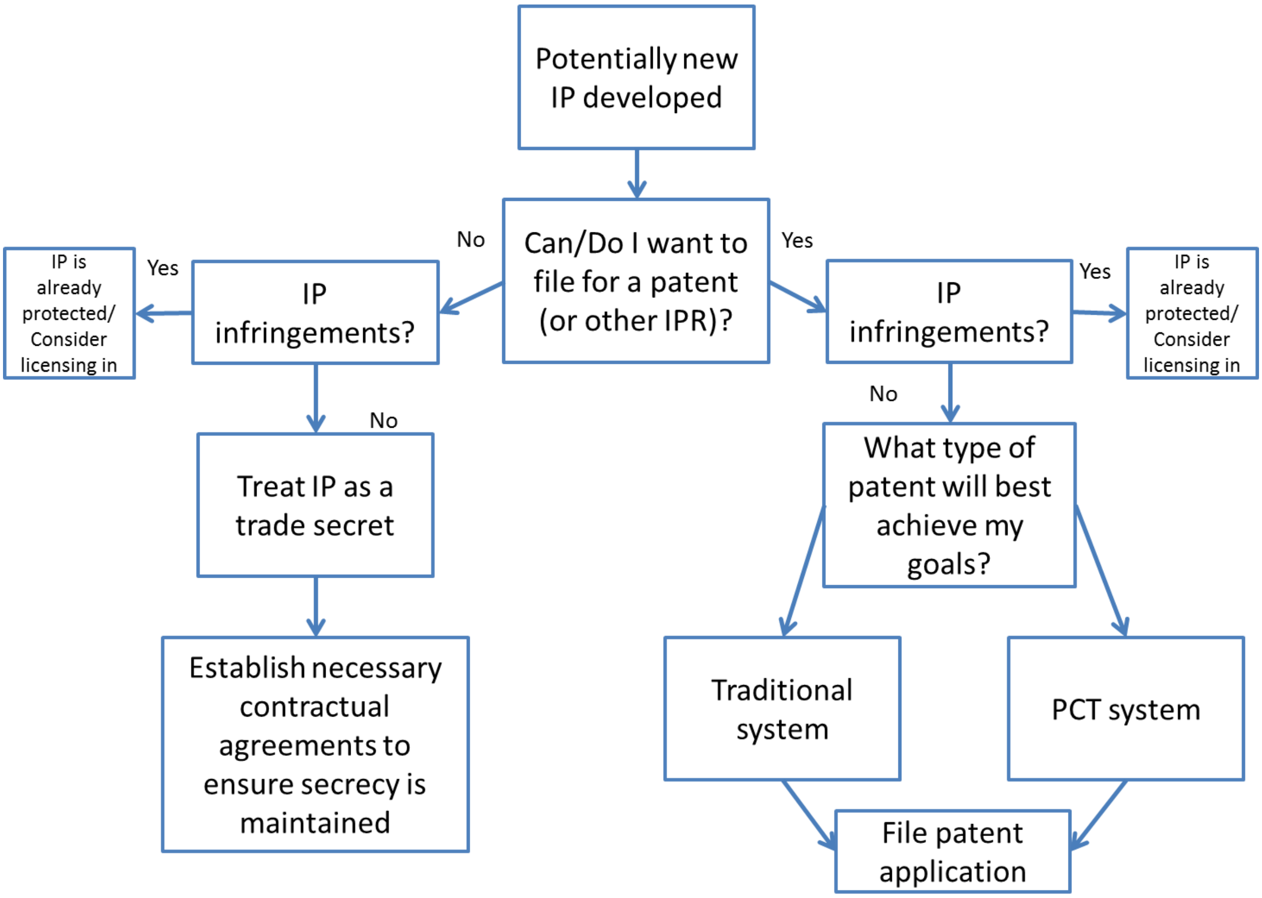

Figure 25: IPR/trade secret decision making process

Once a decision as to how the IP for a new development should be handled, an entity such as InnovUS needs to follow the necessary steps to achieve the protection as well as handle the transfer of the IP to the industrial partners. The physical implementation of the technology or knowledge must be planned and conducted by the research team. This can be done by using the technology transfer model developed and must start by identifying each of the six elements described. These are:

- Transferor
- Transferee
- Technology
- **Transfer mechanism**
- Transferor environment
- Transferee environment

The transfer mechanism is the way in which the technology will be transferred. Examples of what this might be include a licensing agreement, an on-site demonstration or implementation or even something as simple as a meeting between the researchers and industrial users in order to transfer knowledge. In order to determine the best definition of this element for a particular scenario the other five elements should be defined first. The types of technology, as well as the environment into which they are to be transferred are particularly important factors to consider when determining the transfer mechanism. Once the elements have been defined, the transfer mechanism can be carried out and the effectiveness criteria can then be consulted in order to assess the technology transfer. The feedback gained through the transfer activities must aim to shed light upon the transfer process as a whole in order to ensure future transfers are as, if not more, efficient.

The simple flow diagrams for the technology transfer and IP strategies are now represented again in Figure 26, along with the information which has been described for both inputs and potential outputs.

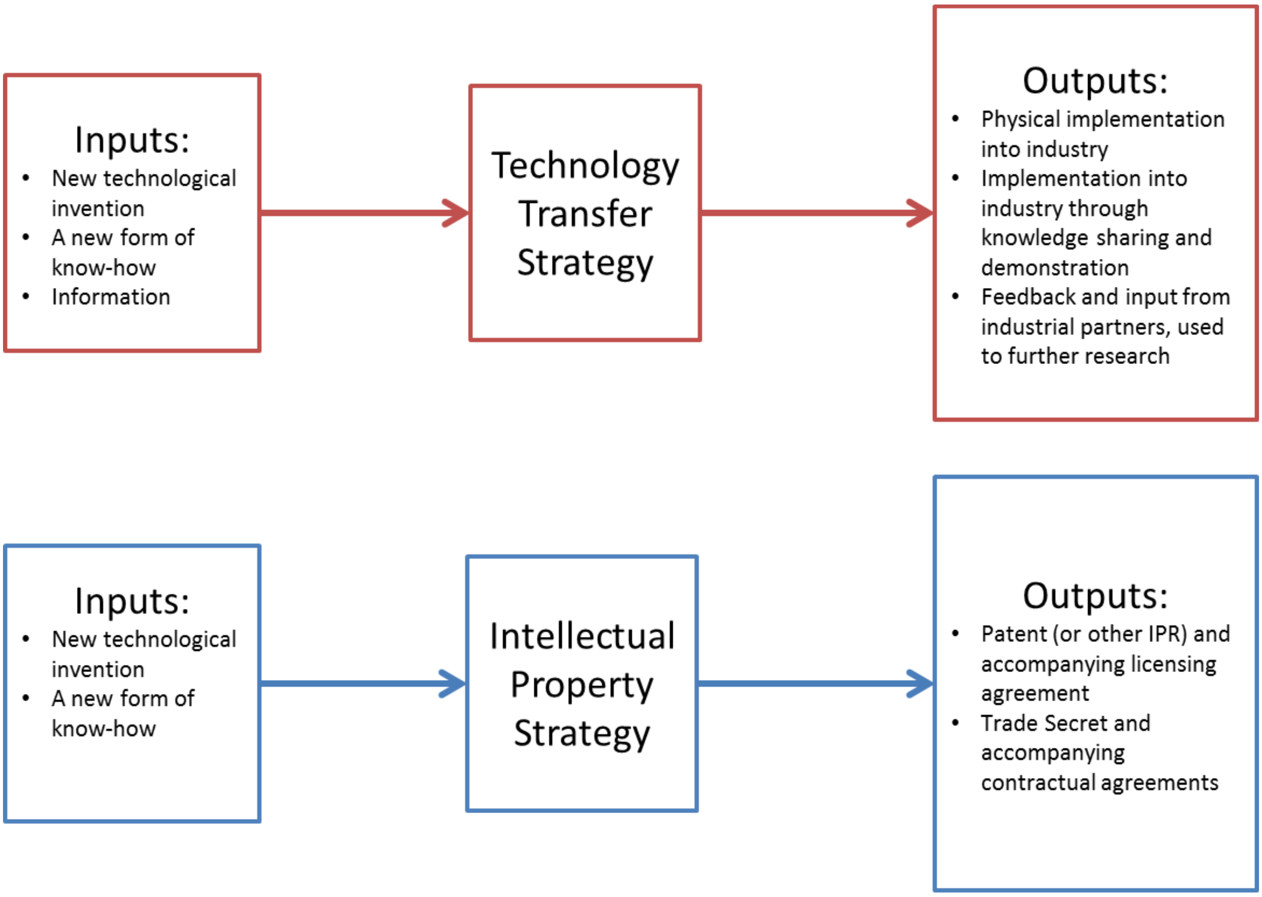

Figure 26: Flow diagrams for technology transfer and IP strategies

6.2 Benefits of the outputs described

The next step in the outcomes plan is to identify the benefits which these outputs would provide to the different parties involved in the research initiative. The different parties involved are described in Table 11.

Table 11: Parties involved in the titanium machining research initiative

Research initiative sector	Parties involved
Funding	Department of Science and Technology (DST)
Research	Stellenbosch University
	Cape Town University
	Johannesburg University
	Fraunhofer Institute for Machining Tools and Forming Technology
Industry	Aerosud
	Daliff Precision Engineering
	Southern Implants

The next table, Table 12, identifies which of these research initiative sectors would benefit **directly** from the potential outputs identified for the technology transfer and IP strategies. This however, does not mean that they will not be beneficial indirectly to other parties involved. For example, although none of these outputs directly benefit the Department of Science and Technology, their ultimate goal of implementing a titanium industry in South Africa is indirectly realised through every output described.

Table 12: Direct output benefits for parties involved

Research initiative sector	Outputs				
	Patent (IPR)	Trade Secret	Physical implementation	Knowledge shared	Feedback
Funding (DST)					
Research	✓	✓		✓	✓
Industry	✓	✓	✓	✓	

Let us now consider each of these sectors individually and some of the other benefits (including indirect benefits as a result of the outputs described) of successful IP protection and technology transfer.

The research institutes involved in the development of titanium machining, particularly the Universities of South Africa, stand not only to benefit through the IPR's which they register, but also through many other ways. These include:

- Experience: Involvement in the titanium machining research provides a means to conduct studies into previously unexplored areas (in South Africa). The chance to conduct these studies alongside some of the leading industrial partners in the country and with the backing of the South African Government will provide valuable experience to all the researchers involved.
- Recognition: To be a part of such an undertaking is a huge privilege for any South African University. Along with its successful implementation comes significant recognition. Through enhanced reputation (and physical facilities), further knowledge transfer and capacity building can be developed. New partnerships as a result of this recognition provide potential access to new pools of students.

- Partnerships: The partnerships formed with both the DST as well as the industrial partners are extremely valuable to any South African University. These partnerships can ensure future collaborations on research and development undertakings. They also create a channel of communication, facilitating the sharing of information between research institutes and industry. Another partnership which is particularly beneficial to the South African universities is the one that exists with Fraunhofer as a result of the titanium machining research initiative. This partnership exposes South African researchers to world class research as well as to the European research culture.
- Students: The involvement in the titanium machining research initiative will result in multiple MSc and PhD degrees being bestowed upon young South Africans. The research opportunities which the titanium machining industry strategy framework provides, creates a means for capacity building and human capital development. Various postgraduate programmes and studies are an efficient way in which to do this and as long as innovative topics are offered and funding is secured, there are enough young people interested in continuing their studies.
- Publications: Along with competitive skills developed come publications, thesis reports and results dissemination.

With regards to the industrial partners involved, the competitive advantages which they stand to gain from this research initiative are huge. Each technology which can be implemented successfully brings them one step closer to being able to enter the global titanium machining industry. However, this is not the only benefit which they stand to achieve. As mentioned earlier, partnerships with the Universities of South Africa provide a tried and trusted means to contract further studies. The collaborative environment of a technology transfer implementation provides a constant source of updated knowledge on not only titanium machining but general machining practices. Another consideration to keep in mind is with regards to the type of license which might be granted to an industrial partner. The options here include either an exclusive license, in which case the industrial partner in question is the only one who will receive the rights to the particular technology, or a non-exclusive license, in which case the technology can be licensed to multiple industrial partners. Which option is chosen depends on the license holder, which in the case of the titanium machining research initiative will be the research institute who develops the new technology. Factors to consider when making this decision should include:

- How much input the industrial partner had in the development of the particular technology in question?
- Is the technology something which would benefit only one particular industrial partner? For example a technology developed which is only useful in machining a dental implant would only stand to provide a benefit to the industrial partner, Southern Implants.
- Which option would best achieve the goals of the entire titanium machining industry strategy? In other words, is it best to distribute the technologies developed amongst all the industrial partners, and possibly other parties in industry in the future? Or give exclusive rights to certain partners?

The general assumption here is that an exclusive license will provide a greater benefit to an industrial partner, particularly through improved competitiveness on a national level. Non-exclusive licenses, however, might make the South African titanium machining industry more competitive on a global level and would still provide the industrial partners involved earlier access to the knowledge than other South African companies.

Lastly, let us consider the potential benefits to the DST, which can be viewed as South Africa as a whole since it is a Government department. Each and every IPR created through this project will be governed by the Intellectual Property from Publicly Financed Research and Development Act, 2008 (Act No. 51 of 2008). This act is intended to "provide for more effective utilisation of intellectual property emanating from publicly financed research and development; to establish the National Intellectual Property Management Office and the Intellectual Property Fund; to provide for the establishment of offices of technology transfer at institutions; and to provide for matters connected therewith". As such, each IPR registered as a result of the titanium machining research initiative can be viewed as an IPR owned by South Africa and for its benefit.

With IPR's and trade secrets created, as well as with the implementation of the technologies which they protect into industry, the goal of the South African titanium industry strategy framework will be realised. With this realisation comes not only the financial benefits, as was shown in Figure 5, of being able to turn raw titanium minerals into final components but also huge potential for job creation that accompanies the implementation of an entirely new industry.

Table 13 summarises the overall benefits identified.

Table 13: Overall benefits for parties involved

Research initiative sector	Benefits identified
Funding	• Successful implementation of a titanium machining industry in South Africa • Job creation as a result of the implementation of a new industry • South African owned IPR's created • Human capital development
Research	• IPR rights developed and owned • Experience and knowledge developed in a new field • Partnerships developed with industry and government • National recognition • Student output (MSc and PhD degrees) • Publications • Funding
Industry	• Access to new technologies developed • Knowledge gained through research outputs • Ultimately the ability to enter the titanium machining industry on a competitive level

6.3 Suggestions to ensure output benefits

In order to ensure that each of the parties involved in the research initiative benefit as described previously, certain suggestions are made with regards to the handling of IP and technology transfer. These suggestions are listed below:

- Ensure a basic level of IP understanding in all personnel involved in the research into titanium machining. This is essential to avoiding unintended public disclosure.
- Document all research thoroughly (Correct dating is important in determining when a technology was first conceptualised)
- Involve InnovUS in all decisions with regards to IP protection, management and transfer. Their professionalism, expertise and experience are an extremely valuable asset to the research team at Stellenbosch University.
- Conduct technology transfer on a level that involves interaction between the people of both the research team and the industrial partners. This is particularly important during the transfer of know-how where an understanding of what has been developed must be imparted rather than just a physical piece of technology.

Chapter 7. Conclusion and Outlook

The aim of this thesis was to develop an IP strategy as well as a technology transfer strategy for the research being conducted into the field of titanium machining as a result of the titanium industry strategy framework being implemented by the South African government. In order to ensure the success of such a research initiative the technological outputs which emerge must ultimately be implemented into industry and provide the end users a competitive edge within their field.

The concern for plans to both protect IP outputs and transfer technologies developed were realised at an early stage, and rightly so. From the outset, there existed no protectable IP, and the technologies being developed were not yet ready to be implemented into industry. As such, an approach was followed in the development of these strategies that would prepare for these scenarios. This required that research be conducted into the fields of IP protection and management as well as technology transfer, however, this was done with the intention of providing information relevant to titanium machining and how research and development into its field would translate through these strategies.

Each new technology developed, along with its respective IP needs to be considered individually. Is the IP in the form of know-how or can it be protected and transferred by patent and a subsequent licensing agreement? Can the new technology be implemented directly into the industrial partner’s environment or do they need to update their systems in some way? Do we even want to pursue an IPR for a new piece of IP or is it unnecessary considering the state of the titanium machining industry in South Africa/globally? These are just some of the questions which could completely alter the way in which one technology is protected and transferred when compared to another. Luckily there is help available when considering how to proceed in such situations. InnovUS, the technology transfer office of Stellenbosch University, who specialise in protecting and transferring new technologies along with its respective IP, is aware of the titanium machining research being conducted. They are always willing to provide guidance and offer their services, which include the protection, licensing, monitoring and on-going support for new developments in technology.

Where the research and development of the titanium machining industry in South Africa is heading, is underlined in the analysis of the technological chain for titanium machining. This is important information to have while developing a technology transfer strategy, as it creates an understanding of the kind of technology which ultimately needs to be transferred and allows for the planning of future implementations into industry. When the technology chain for titanium is considered, the direction of further research is revealed. Tool selection, cooling strategies as well as cutting techniques are some of the aspects of titanium machining which warrant focus in order to improve the efficiency of titanium machining.

A summary of the objectives which were completed in order to develop this thesis are listed below:

- Analysis of the technological chains for titanium machining.
- Development of a technology transfer strategy.
- Development of an intellectual property strategy.
- A presentation of the technology chain implementation, including technology implementations which have occurred to date as well as the plans for future technology transfer.

- Linkage maps detailing which universities will be involved with the different research avenues shown in the plan for research input as well as which industrial partners they will be performed in collaboration with.

The technology transfer model was developed in such a way that it is able to evolve along with new research outputs by use of the feedback mechanism. This can be seen through the implementations which have occurred to date. The environment of the industrial partner Aerosud was expanded upon with each implementation conducted. How their machines and software behave in comparison to the setup at Stellenbosch University was revealed, allowing for future research to take this into account.

For future research into technology transfer and IP protection and management the titanium machining, the following recommendations are made:

- The compilation of an IP portfolio, detailing all research which has been done in the field of titanium machining to date.
- An IP audit, conducted on the portfolio, needs to answer the questions:
  - Have all of our IP assets been identified?
  - Are any of our IP assets able to be registered? If so, do we want to register them or manage them as confidential information?
  - Is any of our IP registered in foreign markets? If not, where would we like to have protection?
  - Is there any IP which other people or company's own which we currently use or intend to use (license agreements)?
  - What is the value of our current IP assets and their future worth? Will they confer a competitive advantage to the industrial partners?
- The implementation of tests for validation purposes at the industrial partners, Daliff Precision Engineering and Southern Implants, in order to begin to develop an understanding of their environments and capabilities.
- Continued liaison with InnovUS to ensure that IP protection and transfer is handled professionally.

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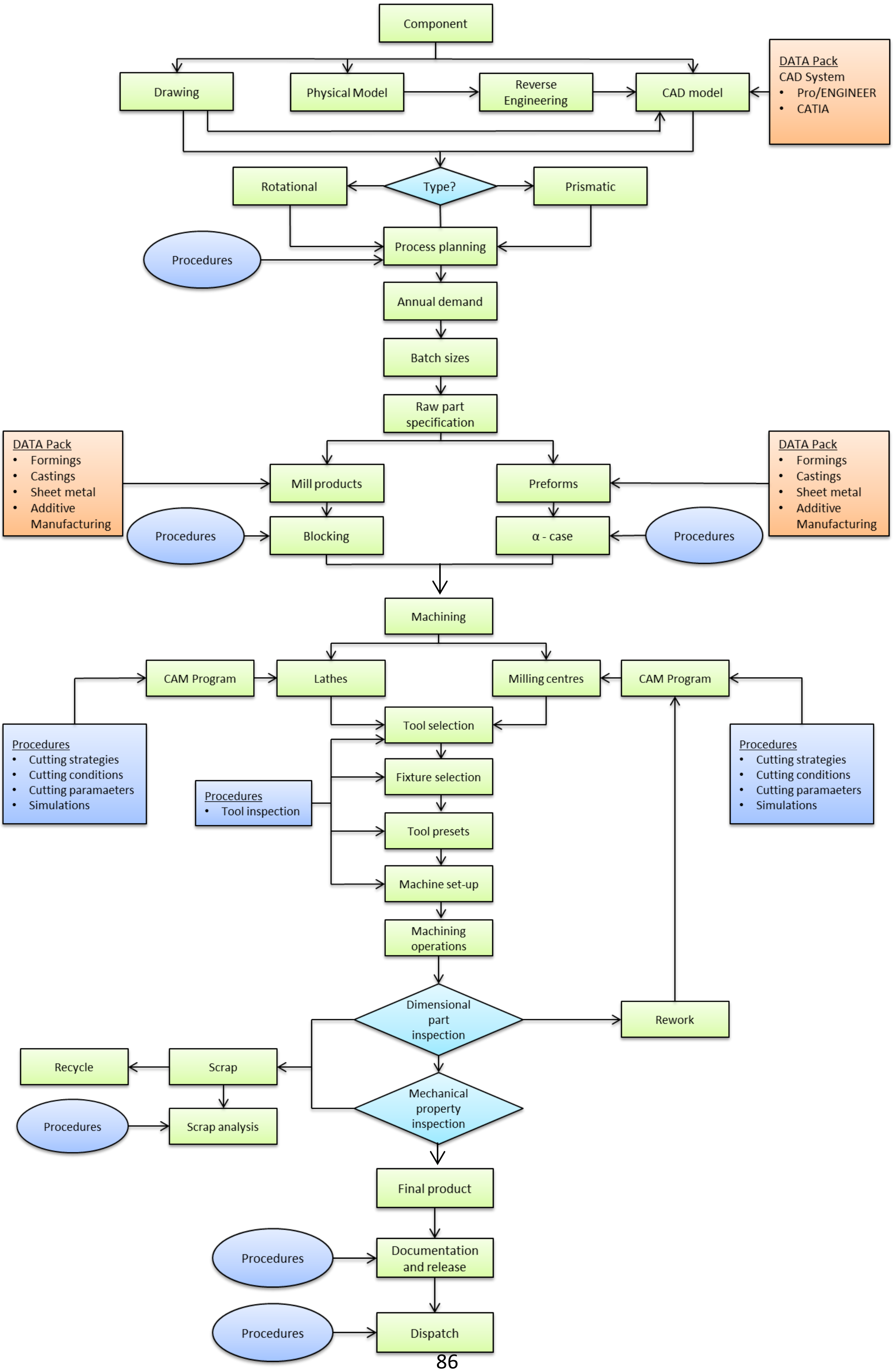
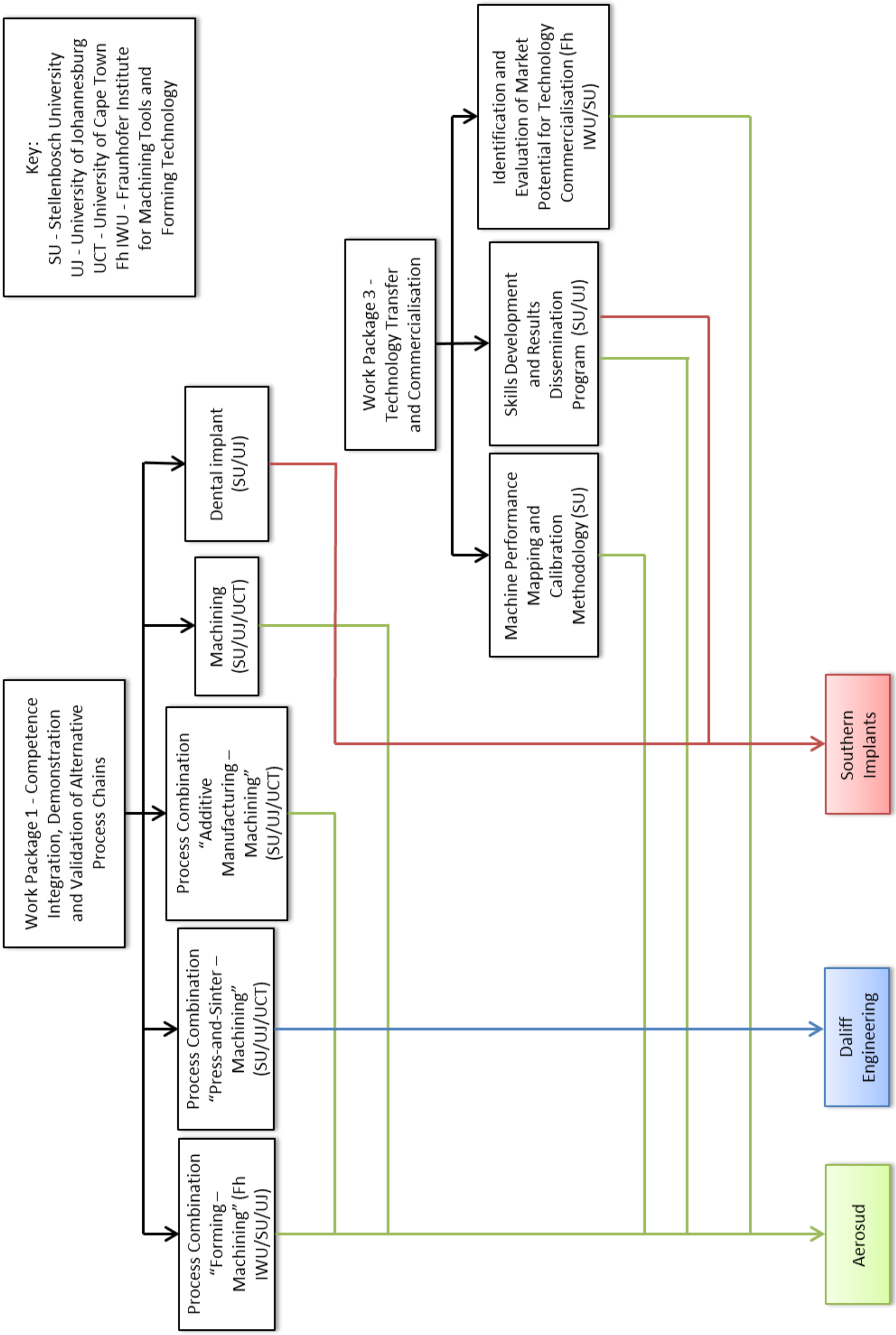
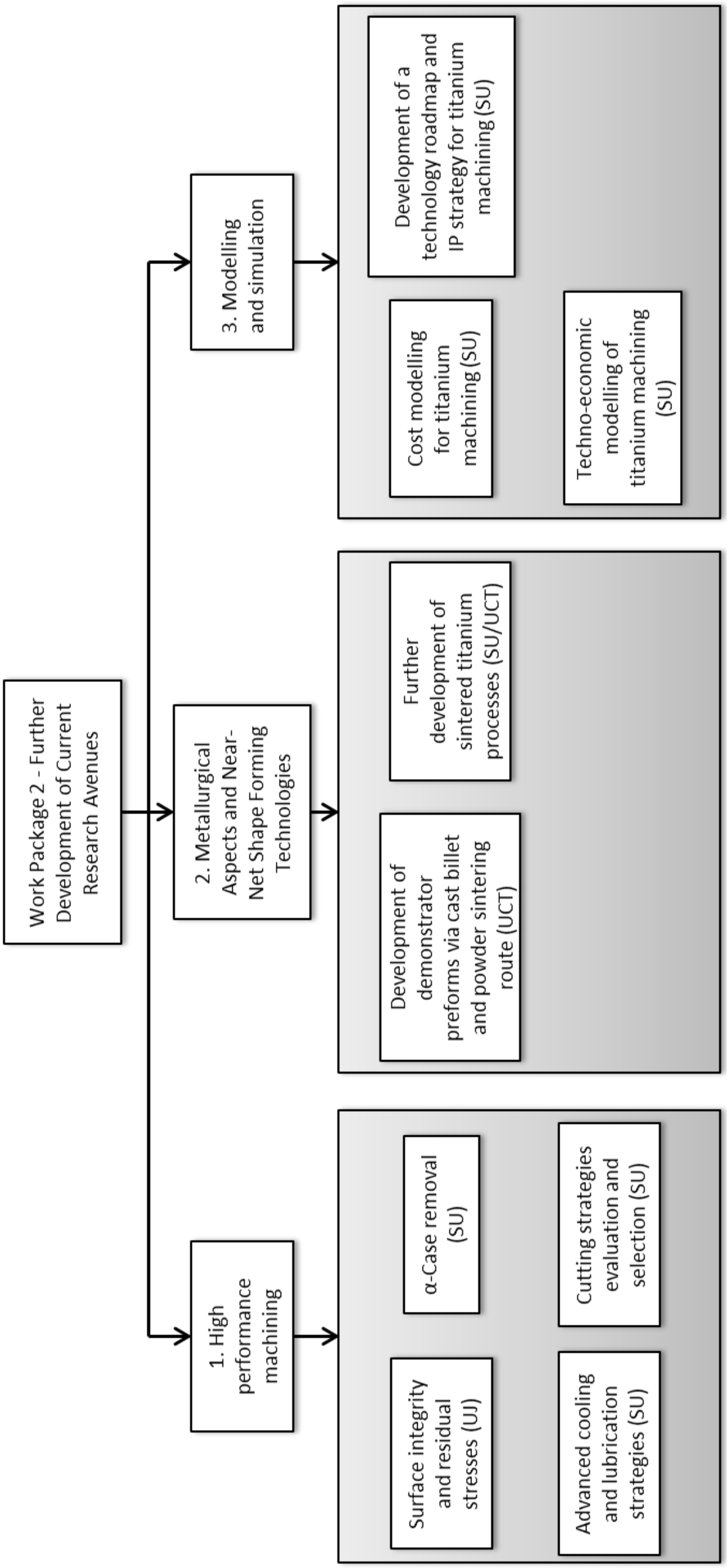
Appendix 1: Machining technology chain



Appendix 2: Complete industrial partner/research institute linkage map




Work Package 2 - Further Development of Current Research Avenues
1. High performance machining
2. Metallurgical Aspects and Near-Net Shape Forming Technologies
3. Modelling and simulation
Surface integrity and residual stresses (UJ)
α-Case removal (SU)
Advanced cooling and lubrication strategies (SU)
Cutting strategies evaluation and selection (SU)
Development of demonstrator preforms via cast billet and powder sintering route (UCT)
Further development of sintered titanium processes (SU/UCT)
Cost modelling for titanium machining (SU)
Development of a technology roadmap and IP strategy for titanium machining (SU)
Techno-economic modelling of titanium machining (SU)

Appendix 3: PCT contracting states

PCT Applicant's Guide – International Phase – Annex A

A PCT Contracting States[1] A

Name of State followed by the two-letter code	Date on which State became bound by the PCT[1]	Name of State followed by the two-letter code	Date on which State became bound by the PCT[1]
Albania AL	4 October 1995	France FR[2, 6]	25 February 1978
Algeria DZ[2]	8 March 2000	Gabon GA	24 January 1978
Angola AO	27 December 2007	Gambia GM	9 December 1997
Antigua and Barbuda AG	17 March 2000	Georgia GE[2]	25 December 1991
Armenia AM[2]	25 December 1991	Germany DE	24 January 1978
Australia AU	31 March 1980	Ghana GH	26 February 1997
Austria AT	23 April 1979	Greece GR	9 October 1990
Azerbaijan AZ	25 December 1995	Grenada GD	22 September 1998
Bahrain BH[2]	18 March 2007	Guatemala GT	14 October 2006
Barbados BB	12 March 1985	Guinea GN	27 May 1991
Belarus BY[2]	25 December 1991	Guinea-Bissau GW	12 December 1997
Belgium BE	14 December 1981	Honduras HN	20 June 2006
Belize BZ	17 June 2000	Hungary HU[2]	27 June 1980
Benin BJ	26 February 1987	Iceland IS	23 March 1995
Bosnia and Herzegovina BA	7 September 1996	India IN[2]	7 December 1998
Botswana BW	30 October 2003	Indonesia ID[2]	5 September 1997
Brazil BR	9 April 1978	Iran (Islamic Republic of) IR	4 October 2013
Brunei Darussalam BN	24 July 2012	Ireland IE	1 August 1992
Bulgaria BG	21 May 1984	Israel IL	1 June 1996
Burkina Faso BF	21 March 1989	Italy IT	28 March 1985
Cameroon CM	24 January 1978	Japan JP	1 October 1978
Canada CA	2 January 1990	Kazakhstan KZ[2]	25 December 1991
Central African Republic CF	24 January 1978	Kenya KE	8 June 1994
Chad TD	24 January 1978	Kyrgyzstan KG[2]	25 December 1991
Chile CL[2]	2 June 2009	Lao People's Democratic Republic LA	14 June 2006
China CN[3, 4]	1 January 1994	Latvia LV	7 September 1993
Colombia CO	28 February 2001	Lesotho LS	21 October 1995
Comoros KM	3 April 2005	Liberia LR	27 August 1994
Congo CG	24 January 1978	Libya LY	15 September 2005
Costa Rica CR	3 August 1999	Liechtenstein LI	19 March 1980
Côte d'Ivoire CI	30 April 1991	Lithuania LT	5 July 1994
Croatia HR	1 July 1998	Luxembourg LU	30 April 1978
Cuba CU[2]	16 July 1996	Madagascar MG	24 January 1978
Cyprus CY	1 April 1998	Malawi MW	24 January 1978
Czech Republic CZ	1 January 1993	Malaysia MY[2]	16 August 2006
Democratic People's Republic of Korea KP	8 July 1980	Mali ML	19 October 1984
Denmark DK	1 December 1978	Malta MT[2]	1 March 2007
Dominica DM	7 August 1999	Mauritania MR	13 April 1983
Dominican Republic DO	28 May 2007	Mexico MX	1 January 1995
Ecuador EC	7 May 2001	Monaco MC	22 June 1979
Egypt EG	6 September 2003	Mongolia MN	27 May 1991
El Salvador SV	17 August 2006	Montenegro ME	3 June 2006
Equatorial Guinea GQ	17 July 2001	Morocco MA	8 October 1999
Estonia EE	24 August 1994	Mozambique MZ[2]	18 May 2000
Finland FI[5]	1 October 1980	Namibia NA	1 January 2004

[Continued on next page]

(4 October 2013)

A PCT Contracting States[1] A

[Continued]

Name of State followed by the two-letter code	Date on which State became bound by the PCT[1]	Name of State followed by the two-letter code	Date on which State became bound by the PCT[1]
Netherlands NL[7]	10 July 1979	Slovakia SK	1 January 1993
New Zealand NZ	1 December 1992	Slovenia SI	1 March 1994
Nicaragua NI	6 March 2003	South Africa ZA[2]	16 March 1999
Niger NE	21 March 1993	Spain ES	16 November 1989
Nigeria NG	8 May 2005	Sri Lanka LK	26 February 1982
Norway NO[5]	1 January 1980	Sudan SD	16 April 1984
Oman OM[2]	26 October 2001	Swaziland SZ	20 September 1994
Panama PA	7 September 2012	Sweden SE[5]	17 May 1978
Papua New Guinea PG	14 June 2003	Switzerland CH	24 January 1978
Peru PE	6 June 2009	Syrian Arab Republic SY	26 June 2003
Philippines PH	17 August 2001	Tajikistan TJ[2]	25 December 1991
Poland PL[5]	25 December 1990	Thailand TH[2]	24 December 2009
Portugal PT	24 November 1992	The former Yugoslav Republic of Macedonia MK	10 August 1995
Qatar QA[2]	3 August 2011	Togo TG	24 January 1978
Republic of Korea KR	10 August 1984	Trinidad and Tobago TT	10 March 1994
Republic of Moldova MD[2]	25 December 1991	Tunisia TN[2]	10 December 2001
Romania RO[2]	23 July 1979	Turkey TR	1 January 1996
Russian Federation RU[2]	29 March 1978[8]	Turkmenistan TM[2]	25 December 1991
Rwanda RW	31 August 2011	Uganda UG	9 February 1995
Saint Kitts and Nevis KN	27 October 2005	Ukraine UA[2]	25 December 1991
Saint Lucia LC[2]	30 August 1996	United Arab Emirates AE	10 March 1999
Saint Vincent and the Grenadines VC[2]	6 August 2002	United Kingdom GB[10]	24 January 1978
San Marino SM	14 December 2004	United Republic of Tanzania TZ	14 September 1999
Sao Tome and Principe ST	3 July 2008	United States of America US[11, 12]	24 January 1978
Saudi Arabia SA	3 August 2013	Uzbekistan UZ[2]	25 December 1991
Senegal SN	24 January 1978	Viet Nam VN	10 March 1993
Serbia RS[9]	1 February 1997	Zambia ZM	15 November 2001
Seychelles SC	7 November 2002	Zimbabwe ZW	11 June 1997
Sierra Leone SL	17 June 1997		
Singapore SG	23 February 1995		

(Total: 148 States)

1 All PCT Contracting States are bound by Chapter II of the PCT relating to the international preliminary examination.
2 With the declaration provided for in PCT Article 64(5).
3 Applies also to Hong Kong, China with effect from 1 July 1997.
4 Not applicable to Macau, China.
5 With the declaration provided for in PCT Article 64(2)(a)(ii).
6 Including all Overseas Departments and Territories.
7 Ratification for the Kingdom in Europe, the Netherlands Antilles and Aruba. The Netherlands Antilles ceased to exist on 10 October 2010. As from that date, the PCT continues to apply to Curaçao and Sint Maarten. The PCT also continues to apply to the islands of Bonaire, Sint Eustatius and Saba which, with effect from 10 October 2010, have become part of the territory of the Kingdom of the Netherlands in Europe.
8 Date of ratification of the Soviet Union, continued by the Russian Federation as from 25 December 1991.
9 Serbia is the continuing State from Serbia and Montenegro as from 3 June 2006.
10 The United Kingdom extended the application of the PCT to the Isle of Man with effect from 29 October 1983.
11 With the declarations provided for in PCT Articles 64(3)(a) and 64(4)(a).
12 Extends to all areas for which the United States of America has international responsibility.

(4 October 2013)

Appendix 4: Madrid protocol contracting states

5. Madrid Agreement Concerning the International Registration of Marks

Madrid Agreement (Marks) (1891), revised at Brussels (1900), at Washington (1911), at The Hague (1925), at London (1934), Nice (1957) and at Stockholm (1967), and amended in 1979

and

6. Protocol Relating to the Madrid Agreement Concerning the International Registration of Marks

Madrid Protocol (1989), amended in 2006 and in 2007

(Madrid Union)[1]

Status on October 14, 2013

State/IGO	Date on which State became party to the Madrid Agreement[2]	Date on which State/IGO became party to the Madrid Protocol (1989)
Albania	October 4, 1995	July 30, 2003
Algeria	July 5, 1972	–
Antigua and Barbuda	–	March 17, 2000
Armenia	December 25, 1991	October 19, 2000[6,10]
Australia	–	July 11, 2001[5,6]
Austria	January 1, 1909	April 13, 1999
Azerbaijan	December 25, 1995	April 15, 2007
Bahrain	–	December 15, 2005[10]
Belarus	December 25, 1991	January 18, 2002[6,10]
Belgium	July 15, 1892[3]	April 1, 1998[3,6]
Bhutan	August 4, 2000	August 4, 2000
Bosnia and Herzegovina	March 1, 1992	January 27, 2009
Botswana	–	December 5, 2006
Bulgaria	August 1, 1985	October 2, 2001[6,10]
China	October 4, 1989[4]	December 1, 1995[4,5,6]
Colombia	–	August 29, 2012[5,6]
Croatia	October 8, 1991	January 23, 2004
Cuba	December 6, 1989	December 26, 1995
Cyprus	November 4, 2003	November 4, 2003[5]
Czech Republic	January 1, 1993	September 25, 1996
Democratic People's Republic of Korea	June 10, 1980	October 3, 1996
Denmark	–	February 13, 1996[5,6,7]
Egypt	July 1, 1952	September 3, 2009
Estonia	–	November 18, 1998[5,6,8]
European Union	–	October 1, 2004[6,10]
Finland	–	April 1, 1996[5,6]
France	July 15, 1892[9]	November 7, 1997[9]
Georgia	–	August 20, 1998[6,10]
Germany	December 1, 1922	March 20, 1996
Ghana	–	September 16, 2008[5,6]
Greece	–	August 10, 2000[5,6]
Hungary	January 1, 1909	October 3, 1997
Iceland	–	April 15, 1997[6,10]
India	–	July 8, 2013[5,6,8]
Iran (Islamic Republic of)	December 25, 2003	December 25, 2003[5]
Ireland	–	October 19, 2001[5,6]
Israel	–	September 1, 2010[5,6]
Italy	October 15, 1894	April 17, 2000[5,6]
Japan	–	March 14, 2000[6,10]
Kazakhstan	December 25, 1991	December 8, 2010
Kenya	June 26, 1998	June 26, 1998[5]
Kyrgyzstan	December 25, 1991	June 17, 2004[6]
Latvia	January 1, 1995	January 5, 2000
Lesotho	February 12, 1999	February 12, 1999
Liberia	December 25, 1995	December 11, 2009
Liechtenstein	July 14, 1933	March 17, 1998
Lithuania	–	November 15, 1997[5]
Luxembourg	September 1, 1924[3]	April 1, 1998[3,6]
Madagascar	–	April 28, 2008[10]
Mexico	–	February 19, 2013[6,10]
Monaco	April 29, 1956	September 27, 1996

5. Madrid Agreement Concerning the International Registration of Marks

Madrid Agreement (Marks) (1891), revised at Brussels (1900), at Washington (1911),
at The Hague (1925), at London (1934), Nice (1957) and at Stockholm (1967), and amended in 1979

and

6. Protocol Relating to the Madrid Agreement Concerning the International Registration of Marks

Madrid Protocol (1989), amended in 2006 and in 2007

(Madrid Union)

(continuation)

State/IGO	Date on which State became party to the Madrid Agreement[2]	Date on which State/IGO became party to the Madrid Protocol (1989)
Mongolia	April 21, 1985	June 16, 2001
Montenegro	June 3, 2006	June 3, 2006
Morocco	July 30, 1917	October 8, 1999
Mozambique	October 7, 1998	October 7, 1998
Namibia	June 30, 2004	June 30, 2004[8]
Netherlands	March 1, 1893[3,11]	April 1, 1998[3,6,11]
New Zealand	–	December 10, 2012[5,6,12]
Norway	–	March 29, 1996[5,6]
Oman	–	October 16, 2007[10]
Philippines	–	July 25, 2012[5,6,8]
Poland	March 18, 1991	March 4, 1997[10]
Portugal	October 31, 1893	March 20, 1997
Republic of Korea	–	April 10, 2003[5,6]
Republic of Moldova	December 25, 1991	December 1, 1997[6]
Romania	October 6, 1920	July 28, 1998
Russian Federation	July 1, 1976[13]	June 10, 1997
Rwanda	–	August 17, 2013
San Marino	September 25, 1960	September 12, 2007[6,10]
Sao Tome and Principe	–	December 8, 2008
Serbia[14]	April 27, 1992	February 17, 1998
Sierra Leone	June 17, 1997	December 28, 1999
Singapore	–	October 31, 2000[5,6]
Slovakia	January 1, 1993	September 13, 1997[10]
Slovenia	June 25, 1991	March 12, 1998
Spain	July 15, 1892	December 1, 1995
Sudan	May 16, 1984	February 16, 2010
Swaziland	December 14, 1998	December 14, 1998
Sweden	–	December 1, 1995[5,6]
Switzerland	July 15, 1892	May 1, 1997[6,10]
Syrian Arab Republic	August 5, 2004[15]	August 5, 2004[5]
Tajikistan	December 25, 1991	June 30, 2011[6,10]
The former Yugoslav Republic of Macedonia	September 8, 1991	August 30, 2002
Tunisia	–	October 16, 2013[5,6]
Turkey	–	January 1, 1999[5,6,8]
Turkmenistan	–	September 28, 1999[6,10]
Ukraine	December 25, 1991	December 29, 2000[5,6]
United Kingdom	–	December 1, 1995[5,6,16]
United States of America	–	November 2, 2003[5,6]
Uzbekistan	–	December 27, 2006[6,10]
Viet Nam	March 8, 1949	July 11, 2006[6]
Zambia	–	November 15, 2001
Total: (92)	(56)	(91)

[1] The Madrid Union is composed of the States party to the Madrid Agreement and the Contracting Parties to the Madrid Protocol.

5. Madrid Agreement Concerning the International Registration of Marks

Madrid Agreement (Marks) (1891), revised at Brussels (1900), at Washington (1911), at The Hague (1925), at London (1934), Nice (1957) and at Stockholm (1967), and amended in 1979

and

6. Protocol Relating to the Madrid Agreement Concerning the International Registration of Marks

Madrid Protocol (1989), amended in 2006 and in 2007

(Madrid Union)

(continuation)

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[2] All the States party to the Madrid Agreement have declared, under Article 3*bis* of the Nice or Stockholm Act, that the protection arising from international registration shall not extend to them unless the proprietor of the mark so requests.

[3] The territories of Belgium, Luxembourg and the Kingdom of the Netherlands in Europe are to be deemed a single country, for the application of the Madrid Agreement as from January 1, 1971, and for the application of the Protocol as from April 1, 1998.

[4] Not applicable to either Hong Kong, China or Macao, China.

[5] In accordance with Article 5(2)(b) and (c) of the Protocol, this Contracting Party has declared that the time limit to notify a refusal of protection shall be 18 months and that, where a refusal of protection results from an opposition to the granting of protection, such refusal may be notified after the expiry of the 18–month time limit.

[6] In accordance with Article 8(7)(a) of the Protocol, this Contracting Party has declared that, in connection with each request for territorial extension to it of the protection of an international registration and the renewal of any such international registration, it wants to receive an individual fee, instead of a share in the revenue produced by the supplementary and complementary fee.

[7] Not applicable to the Faroe Islands but applicable to Greenland as of January 11, 2011.

[8] In accordance with Article 14(5) of the Protocol, this Contracting Party has declared that the protection resulting from any international registration effected under this Protocol before the date of entry into force of this Protocol with respect to it cannot be extended to it.

[9] Including all Overseas Departments and Territories.

[10] In accordance with Article 5(2)(b) of the Protocol, this Contracting Party has declared that the time limit to notify a refusal of protection shall be 18 months.

[11] The instrument of ratification of the Stockholm Act and the instrument of acceptance of the Protocol were deposited for the Kingdom in Europe. The Netherlands extended the application of the Madrid Protocol to the Netherlands Antilles with effect from April 28, 2003. The Netherlands Antilles ceased to exist on October 10, 2010. As from that date, the Protocol continues to apply to Curaçao and Sint Maarten. The Protocol also continues to apply to the islands of Bonaire, Sint Eustatius and Saba which, with effect from October 10, 2010, have become part of the territory of the Kingdom of the Netherlands in Europe.

[12] With a declaration that this accession shall not extend to Tokelau unless and until a declaration to this effect is lodged by the Government of New Zealand with the depositary on the basis of appropriate consultation with that territory.

[13] Date of accession by the Soviet Union, continued by the Russian Federation as from December 25, 1991.

[14] Serbia is the continuing State from Serbia and Montenegro as from June 3, 2006.

[15] The Syrian Arab Republic deposited, on June 29, 2012, an instrument of denunciation of the Madrid Agreement. The said denunciation will become effective, with respect to this State, as from June 29, 2013.

[16] Ratification in respect of the United Kingdom and the Isle of Man.

Appendix 5: Section 2 and 3 of Act no. 51 of 2008

Objects of the Act

2. (1) The object of this Act is to make provision that intellectual property emanating from publicly financed research and development is identified, protected, utilised and commercialised for the benefit of the people of the Republic, whether it be for a social, economic, military or any other benefit.

(2) This Act furthermore seeks to ensure that -

(a) a recipient of funding from a funding agency assesses, record" and reports on the benefit for society of publicly financed research [md development;

(b) a recipient protects intellectual property emanating from publicly financed research and development from appropriation and ensures that it is available to the people of the Republic;

(c) a recipient identities commercialisation opportunities for intellectual property emanating from publicly financed research and development;

(d) human ingenuity and creativity are acknowledged and rewarded;

(e) the people of the Republic, particularly small enterprises and BBBEE entities, have preferential access to opportunities arising from the production of knowledge from publicly financed research and development and the attendant intellectual property;

(j} following the evaluation of a disclosure, researchers may publish their research findings for the public good; and

(g) where necessary, the State may use the results of publicly financed research and development and the attendant intellectual property in the interest of the people of the Republic.

Application of the Act

3. (1) This Act applies to intellectual property emanating from publicly financed research and development.

(2) (a) Subject to paragraph (b), the Minister may, in addition to the institutions to which this Act applies, by notice in the Gazette, identify any other institution to which this Act applies if he or she is satisfied that the institution may develop intellectual property from publicly financed research and development.

(b) Any identification contemplated in paragraph (a) must be done with the concurrence of the Minister responsible for the institution concerned.

Appendix 6: InnovUS disclosure form

STELLENBOSCH UNIVERSITY

INNOVUS

DISCLOSURE FORM

The purpose of this form is to disclose information on a new business idea or innovation to the University. This will enable the University to support the initiative of the party concerned and to ensure that all possible intellectual property rights (including expertise) are sufficiently protected on behalf of both the individual and the University. Such disclosure of information by the individual concerned and support by the University will enable the individual and the University to commercially exploit such ideas in partnership and to protect the rights of the entrepreneur(s).

1. Name of the innovation

Approach to cost modeling for titanium machining in industrial applications

2. Background to the innovation

2.1 Which known technology (prior art) related to the innovation already exists?

Currently there are several theoretical cost models for manufacturing processes of various metals. There is however not one specifically for milling operations of titanium. Most of the generic cost models that are available are very complex and require extensive mathematical modeling. A simplified aproach for industrial application does not exist and that is the aim of this research.

2.2 Of which publications or patents concerning the known technology are you aware? Please attach.

As stated, there are numerous publications for cost models for manufacturing a variety of metals. No publications were found on setting up a specific aproach for milling of titanium parts.

3. The innovation

Type of innovation (please tick box)			
Invention		Multi-media	
Business idea		Written work	
Plant breeders' rights		Procedural	✓
Intellectual property in research contract		Registration	
Software		Diagnostic	
Therapeutic		New species	

Please indicate in which category your technology falls (✓):

AGRI SCIENCES		MEDICINE AND HEALTH	
Agronomy		Diagnostics	
Aquaculture		Health Biotechnology	
Integrated Pest Management		Medical Devices	
Food Science		Services	
Wine Biotechnology		Therapeutics and Pharmaceutics	
ENGINEERING		**PHYSICAL SCIENCES**	
Electrical Engineering		Chemistry and Polymer Science	
Marine Engineering		Nanotechnology	
Mechanical Engineering	✓	Software and Models	
Process Engineering		**GREEN ENERGY**	
LIFE SCIENCES		Biofuels	
Biochemistry		Power Generation	
Cultivars		Renewable Energy	
Industrial Biotechnology		Solar Energy	
Plant Biotechnology		Wave Energy	
		Wind Energy	

Shortly describe the innovation here, but attach a **complete** description with as much detail as possible, sketches etc., including equipment used, procedures followed and results obtained.

The cost model approach will make it possible to approximate the costs that are associated with machining a titanium part with a specific machine setup. Since every machine is different it is not possible to use a generic cost model to determine the costs. A certain aproach must be followed so that the costs that is specific to certain setup can be determined. The procedures in this aproach will be determined using experimental trials and information from academic literature. The experimental trials will be performed on the Hermle C40U at Stellenbosch University (SU). Once the approach is developed, it will be tested at SU and validated in industry.

Which **problems associated** with the existing technology does this innovation solve?

The problems with current cost models are that they are not specifically designed for titanium machining. This cost model approach is specifically designed for titanium milling operations.

Which other **benefits** does the innovation offer?

The proposed cost model approach is aimed at industrial application and will therfore be simplified to make it user friendly and easy to implement. Many generic cost models are complex and not specifically suited for industrial application.

Where and when did the idea originate?

The idea originated as part of the titanium research project that have been running over the past few years under the auspices of a Titanium Centre of Competence (TiCoC). The need for such an approach was identified as the titanium machining technolgy was transfered to industry who did not have a way to determine the costs.

Has the idea been disclosed either in writing (whether by email or publication) or verbally and, if so, where and to whom?

No

Do you have a working prototype of the product and are test results available?
No

Can the technology be demonstrated?
Not ready

What is the development status of this technology? What further industrialisation is necessary to produce a commercial end-product?
The approach is still being developed.

Who will typically be the clients who will acquire this technology?
Manufacturing industry involved with titanium machining in South Africa.

4. Third parties

Is this innovation the result of a research contract? If so, please provide more information.
Yes, the titanium machining project titled: Resource Efficient Process Chains for Titanium Components in Aerospace, Automotive, and Medical Applications.

Who financed the research?
South African Department of Science and Technology (DST)

5. Inventor(s) and non-inventors(s) (personal and employment details)

IMPORTANT: Please provide us with your fully updated personal and employment details. This will be necessary to process your disclosure and to process the reports and distribution of income that might occur.

1. Inventor / non-inventor:	
Full name of inventor	Pieter Conradie
Full name of non-inventor	
Definition of inventor: Any and all persons who made an inventive contribution to the invention that is the subject of the patent application. For the sake of clarity, only those aspects of the described subject matter that are both new and inventive in light of the prior art, and as such qualify for patent protection, qualify as inventive contributions. **Definition of non-inventor:** Any and all persons, other than those that fall within the definition of "inventor", who made a substantial contribution to the project and who, by agreement between the parties, will share in the benefits derived from it.	
Contact particulars:	
Telephone number	
Fax number	
Email address	
Physical home address	
% Contribution distribution	
Disclosure date	
Signature	

Employment details:	
Position at SU	PhD Engineering student
Faculty	
Department	
SU number	
2. Inventor / non-inventor:	
Full name of inventor	
Full name of non-inventor	
Contact details:	
Telephone number	
Fax number	
Email address	
Physical home address	
% Contribution distribution	
Disclosure date	
Signature	
Employment details:	
Position at SU	
Faculty	
Department	
SU number	
3. Inventor / non-inventor:	
Full name of inventor	
Full name of non-inventor	
Contact details:	
Telephone number	
Fax number	
Email address	
Physical home address	
% Contribution distribution	
Disclosure date	
Signature	