Imperial College London
BUSINESS SCHOOL

Dual-use Technology Transfer Between Defence and Non-defence Markets

Thesis submitted for the award of Doctor of Philosophy (Ph.D.)

Imperial College London Business School

Liam Jon Kieran HARRIS

Abstract

Defence procurement easily matches and exceeds virtually any other form of technology-intensive procurements by the government. Additionally, defence procurement often focuses on technologically advanced, engineering-intensive equipment. This represents a significant potential for technological innovation and subsequent diffusion of this innovation throughout the economy.

The defence industry has often been considered insular and idiosyncratic, meeting the demands of a bureaucratic, central buyer, creating firms unable to compete in dynamic commercial markets, and posing a barrier for innovative firms to enter.

This study poses the question: When is technology likely to transfer into or out of the defence sector? Which organisational-level factors facilitate or hinder the likelihood and success of such technology transfer?

By combining organisational identity, capabilities and institutional theories, this thesis pursues a novel approach to the problem, and we find that organisational identity moderates the capability-performance relationship – in essence, a strong organisational identity is negatively associated with the likelihood that a firm will deploy its resources in unfamiliar markets, or to exploit technologies present in them. The defence industry provides a salient context for the study of this phenomenon.

This thesis presents a current overview of the UK defence sector, by reviewing the existing literature in the field and updating it with consideration to the significant changes which the industry has faced. This includes a review of the previous research on firm-level factors which influence the transfer of technology into and out of the sector. An organisational identity theory of capability deployment is then developed, and tested with a combination of expert interviews and quantitative analysis of the results of a survey of firms in the UK defence sector.

The resulting analysis and discussion contribute to the understanding of the UK defence sector in the modern world, and the potential barriers to fully exploit technology developed in the defence context, and to the factors which may influence the UK armed forces' access to technologies from non-traditional sources.

Further, the recognition that institutional forces can influence organisational identity and subsequently affect the deployment of capabilities, I contribute to the management literature by suggesting a link between the rarely connected literatures on organisational identity and capabilities.

Declaration

I herewith certify that all material in this dissertation which is not my own work has been properly acknowledged.

Liam Jon Kieran Harris

For my Grandmother, Eleanor V. Harris

Acknowledgements

The number of people who supported this thesis is so great that I am bound to miss some. In fact, one defining characteristic and major source of enjoyment of this project was its basis on the interaction with such a diverse range of people. Anyone who is missed will know who they are and will know that their assistance, whatever form it took, is greatly appreciated.

I would firstly like to thank Julia, for her ongoing support and encouragement. Without her, this project would never have been completed. I understand the difficulties involved in being a passenger in this crazy journey which we call a PhD. Your backing, patience, belief and understanding will never be forgotten.

My family have also been a solid foundation on which my efforts have been built. The phone calls and visits have had a far stronger effect than you will ever know.

I would also like to thank my supervisor Erkko Autio for the helpful input and insights, and the inspiration in building my own theoretical knowledge. This has been essential in framing this complex range of problems and has influenced my professional and personal development greatly.

I also gained valuable assistance and support from other colleagues at Imperial College Business School, notably Paola Criscuolo, and many of my fellow PhD students. Talks with these people often helped my stay on the right course. I would particularly like to thank Julie Paranics for her invaluable support throughout the process.

I have benefitted from such a wide range of efforts from academics and industry experts in so many contexts. I will always be indebted to this support and would particularly like to thank Tim Martin at A|D|S for his patience and important support, Puay Tang for introducing me to the industry, and Andrew Middleton, for starting me on this journey. Of course the entire project was only possible due to EPSRC and QinetiQ funding.

This list could go on and on, but I would also like to thank my friends and family who have not been mentioned so far, particularly Julia's family who have always taken an interest and supported me in many ways.

Table of Contents

Index of Tables and Figures

Index of Appendices

List of Abbreviations

B2C	Business-to-Consumer
C4ISTAR	Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition, and Reconnaissance
CADMID	Concept - Assessment - Demonstration - Manufacture - In-Service - Disposal
CADMIT	Concept - Assessment - Demonstration - Migrate - In-Service - Termination
CDE	Centre for Defence Enterprise
COTS	Commercial off the shelf
CVX	CVX Next Generation Aircraft Carrier
DASA	Defence Analytical Services and Advice
DC	Defence Contractor
DIB	Defence Industrial base
DU	Dual-Use
DUT2	Dual-Use Technology Transfer
EPSRC	Engineering and Physical Sciences Research Council
FAME	Financial Analysis Made Easy
IPT	Integrated Project Team
JSF	Joint Strike Fighter
KTN	Knowledge Transfer Network
MOD	Ministry of Defence
NAO	National Audit Office
NRBC	Nuclear, Radiological, Biological, Chemical
SME	Small and medium sized enterprises
smtp	Simple Mail Transfer Protocol
SSL	Secure Sockets Layer
TLS	Transport Layer Security

1 Introduction

Defence procurement represents a major share of public-sector economic activity in many countries (Sandler & Hartley, 2007). In the United Kingdom, for example, the Defence Equipment and Support department of the Ministry of Defence employs over 22,000 people and administers an annual procurement budget of £14 billion (Great Britain. Ministry of Defence, DASA, 2011). At these levels, defence procurement easily matches and exceeds virtually any other form of technology-intensive procurements by the government.

In addition to scale, defence procurement typically focuses on technologically advanced, engineering-intensive items (Alic et al., 1992; Rogerson, 1994). Because of its scale and technology-intensity, defence procurement represents a major potential source of technological and economic advances (Ram, 2007). Examples of technological spill-overs from defence to the civilian economy are, indeed, numerous, including radar, numerous metallurgical applications, carbon fibre, Kevlar, semiconductors, satellite technologies, internet infrastructure, optical communications and nuclear power. Such examples of 'dual-use technology transfer' (DUT2) testify of a significant potential for technological innovation associated with defence-related government procurement (Molas-Gallart, 1999).

Although the technological innovation potential associated with defence procurement is significant and practical examples numerous, there has been fairly little micro-level research into the determinants of the likelihood and success of technological spill-overs from military to civilian application (Molas-Gallart, 1997). Whilst there exists an important array of macro-level studies documenting links between defence and civilian sectors, as well as associated economic impacts, there are only few studies seeking to understand micro-level determinants of when, and under which conditions defence-related technological spill-overs are more likely to occur, and what determines the outcome of such spill-overs. This is an important gap, given that spill-overs actually occur at the micro-level rather than at the macro-level and that spill-overs do not occur automatically. For example, the massive investment of the Soviet Union into its defence sector produced little visible spill-over impact in the civilian economy. On the other hand, some studies claim that the Silicon Valley itself would not exist today, had it not been for the US investment in defence procurement in the State of California (Heinrich, 2002). Clearly, spill-over does not follow automatically from investment into defence procurement. We expect that the factors regulating spill-over are likely to be found at an organisational level of analysis. It is the general objective of this thesis to identify factors that facilitate or hinder the spill-over of technologies from the defence to the civilian sectors.

The defence sector offers a distinctive context for the study of technology transfer processes, one that offers significant potential for the derivation of theoretical insights. The defence sector is

characterised by strong institutions and unique practices (Hartley, 2007), which define appropriate behaviours and acceptable practices (DiMaggio, 1988; Scott, 2001). In order to be accepted as legitimate suppliers, defence technology companies face strong pressure to conform to accepted institutional norms (Oliver, 1991; Rogerson, 1994). Such institutional pressures to conform are reinforced by the distinctive characteristics of the defence procurement environment, which prompt defence suppliers to develop capabilities that are idiosyncratic to the defence sector. Unlike in most civilian sectors, the defence sector is dominated by one dominating buyer, the Ministry of Defence (MOD). Defence procurements typically take the form of large, long-term projects, often characterised by a high degree of technological uncertainty. Project deliveries in the defence sector are typically punctuated by milestones, defined in terms of Technology Readiness Levels (TRLs) (Hartley, 2007). The control milestones are designed to ensure that even high-uncertainty projects are delivered on time and within budget. To achieve timely delivery and to provide buffer against technological uncertainty, defence procurement contracts typically take the form of 'cost-plus' contracts that guarantee (within limits) a minimum profit for the supplier, thereby encouraging them to allocate appropriate resources whenever uncertainties emerge. We expect that these attributes of the defence procurement process will prompt defence suppliers to develop idiosyncratic capabilities, which, although optimised for defence procurement, may turn into a source of rigidity when defence suppliers attempt diversification to civilian sectors.

In theoretical terms, this project also presents the opportunity to advance the understanding of when organisational capabilities become rigidities, and how these rigidities play out in DUT2 situations. The defence sector provides a complex context for research, being a well defined, distinctive, and rather insular industry sector (in terms of cross-sectoral linkages). The defence sector is subject to heavy isomorphic pressures and exhibits distinctive procurement processes. The chosen context of empirical research will therefore offer potential for generating new theoretical insights both for institutional and organisational capability theories, particularly when seeking to understand when isomorphic processes and distinctive optimisation of organisational capabilities give rise to organisational rigidities that inhibit the ability of technology-intensive companies to diversify beyond their home sectors (Leonard-Barton, 1992).

The specific case of defence-related DUT2 is also likely to be generalisable to wider contexts, in particular to cases where one party to the technology transfer process operates in a highly regulated, idiosyncratic (in terms of inter-organisational transactions) and procurer-dominated environment. Overall, we expect that our empirical context is conducive to understanding how organisations can overcome the "wall of separation" (Markusen & Yudken, 1992) that demarcates the boundaries of adjacent organisational fields, when seeking to extend the applications of their knowledge-intensive products and services beyond their original setting.

Further, we expand our analysis of DUT2 to include the transfer of technology into the defence sector, i.e. the application of technologies developed elsewhere in the defence sector. This issue is increasingly important in the context of defence procurement.

Consistent with the above, we seek three distinctive contributions in this research:

1 To broaden the theoretical and empirical understanding with regard to the effect of defence sector involvement on the likelihood and outcomes of DUT2 processes;

2 To broaden the theoretical and empirical understanding with regard to the effect of institutional isomorphic pressures on the likelihood and outcomes of DUT2 processes;

3 To broaden the theoretical and empirical understanding with regard to the effect of capability optimisation-induced rigidities on the likelihood and outcomes of DUT2 processes.

The above considerations suggest four specific research questions that this research should address. The overarching theme of this research addresses how technology and underlying technological capabilities flow from military to civilian applications, and vice versa. In order to study technology transfer processes in this empirical context, a hierarchical approach is necessary. The institutional environment of the sector must be analysed and mapped, in order to ascertain how the institutional context both constrains and facilitates technology transfer processes at the organisational level. Insights from such influences will then guide the analysis of factors influencing the probability of engagement in DUT2, as well as its success at the organisational level. This research, therefore, addresses the following questions:

RQ1 What are the institutional and isomorphic pressures that characterise the defence procurement sectors, and how do they facilitate and constrain DUT2 processes?

RQ2 How are these pressures experienced at the level of defence supplier firms?

RQ3 How does the idiosyncratic optimisation of delivery capabilities within the defence procurement sector constrain DUT2 processes?

RQ4 In which situations is DUT2 most likely to occur, and what are the organisational-level determinants of its success?

In this research we seek to advance the understanding of the complex processes of DUT2.

Next, we provide a brief overview of the empirical context of this research – i.e., the defence industrial base. After this, we provide a brief overview of the DUT2 literature. Following this literature review, we develop an initial theoretical model for empirical research. After the theoretical model development, we provide a new account of the research methods, focusing this time on the implementation of the different research stages. Subsequently, we analyse the results from the statistical analysis of the empirical research results, and continue by discussing these results, and finally outlining the implications of these conclusions.

2 Industrial Context – The UK Defence Sector

This section intends to give an overview of the defence industrial context. This is imperative in the case of this project, as the sector exhibits many idiosyncratic characteristics. The sector is both complex and insular, and therefore a contextual description could be incredibly lengthy and involved, so here we focus on creating an overview of the most pertinent aspects, which contribute to the institutional forces which we suggest lead to the organisational adaptation specific to the defence environment.

First we shall provide an overview of the scale and scope of the UK defence Industry. Subsequently the institutional environment and its implications will be addressed. At this point it is necessary to define the industry, as the MOD and other defence agencies procure from firms, which often also produce non-defence products and services. These can be differentiated into products with separate and distinct non-defence applications, and dual-use products.

2.1 The UK defence sector, scale and scope

The Defence Analytical Services and Advice (DASA) provides statistics relating to defence spending in relation to wider government spending. They state that total government spending in the fiscal year 2009/10 amounted to £655.2 billion. Defence spending accounted for £39.5 billion. MOD's equipment spend for the period is estimated at £14 billion, of which ca. £7 billion constituted capital expenditure on equipment, £4.6 billion for equipment support and £2.4 billion for R&D (Great Britain. Ministry of Defence, DASA, 2011).

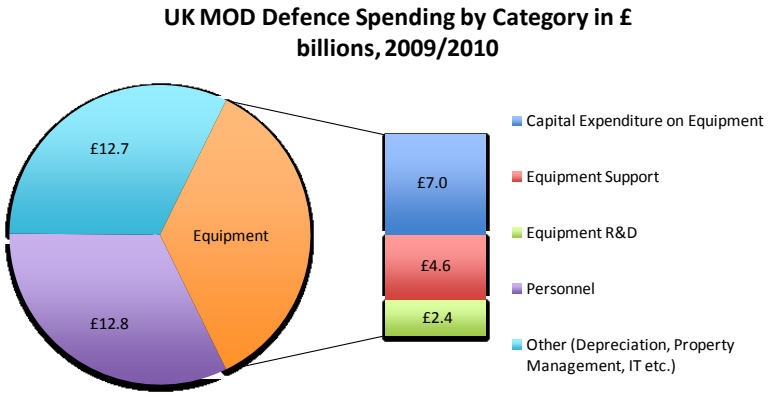

Figure 1: UK MOD defence spending by category in £ billions in 2009/2010 (Great Britain. Ministry of Defence, DASA, 2011)

Due to the nature of the equipment procured by the MOD, single firms often receive large contracts that extend from the R&D phase through to equipment support. Figure 2 illustrates the structure of contracts awarded to individual firms in 2009/2010 (Great Britain. Ministry of Defence, DASA, 2011):

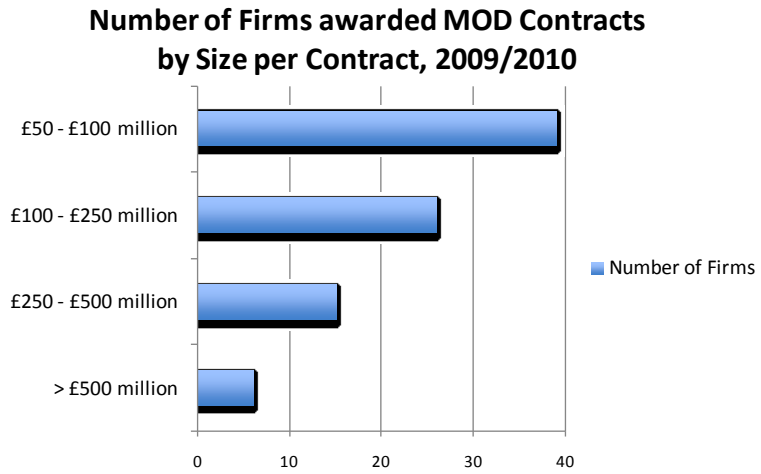

Figure 2: Number of firms awarded MOD contracts by contract size in 2009/2010 (Great Britain. Ministry of Defence, DASA, 2011)

With this level of spending on procurement, support and R&D, defence budgets represent a significant market for firms willing and able to sell to the MOD.

2.2 Dual-Use and the intersection of the defence sector and the wider economy

Dual-use products (and technologies in general) can be defined as any products or technologies, which have both defence and non-defence applications (Molas-Gallart, 1997)[1]. Such products are present through all levels of technological sophistication, from e.g. clothing and food supplies, to complex systems such as transport helicopters. Although military specifications may require some customisation to fulfil military requirements, certain helicopter designs can be effectively used in either sector. The same can also be said for the less technologically sophisticated, but highly important products and technologies associated with military operations, such as the aforementioned clothing and food.

As this study is focused on the relationship between defence and non-defence technologies, we primarily focus on the effect that defence spending has on technological development, and the subsequent effect on non-defence products and technologies. Therefore this study will concentrate

[1] For a more detailed definition and discussion on technology and dual-use, please refer to section 3.1, p. 36

on technological innovation, and pay less attention to the procurement of commodities and "low-tech" products.

Many firms, which are involved in many technological fields, are involved in defence procurement. The potential for DUT2 will of course be related to the particular field. For example, there is less scope for civilian applications for missile systems, or stealth technology, compared to developments in navigation or telecommunications. Arms control regulations and military secrecy can also affect the potential for transfer, particularly for technologies such as those relating to stealth or nuclear power.

Defence spending represents one of the largest, if not the largest technology-intensive government procurement activities in many developed countries. Defence agencies are often willing to pay a premium to obtain a technological advantage (Middleton et al., 2006). Therefore they will often take on the role of early adopters of new technologies. Practically this means that through the volume but also the structure of defence spending, technology research, development and maturation can be funded which may not have attracted investment in a free market context.

This phenomenon has been conceptualised as the cash flow "valley of death", whereby a lack of funding may cause an R&D project to fail due to a lack of funding and high costs associated with the pre-commercialisation phases of the project (Murphy & Edwards, 2003). In essence, as no revenue is being generated, costs are being incurred, and the project has a high level of risk and uncertainty associated with it, such that external impetus may be required to ensure the project proceeds to completion. In such cases in the defence context, defence agencies may provide the necessary funding which was unavailable from other sources, in order for the technology to reach the market.

2.3 The changing strategic defence context

The context surrounding defence procurement has changed significantly in the last quarter of a century. The end of the cold war, and the emergence of the threats related to international terrorism have greatly affected the volumes and the nature of military systems. The following statement from a retired senior military officer sums up the significant changes:

> *"The cold war was about large mechanical weapons (tanks, guns etc.) slogging it out in the East European land mass, together with sophisticated aircraft and nuclear weapons. Not much use for any of these technologies in the civil sector. Also the procurement of these weapon systems could take 10 - 15 years (the civil sector would go bust if anything took this long!). But now, the changing threat requires rapid acquisition and a*

high electronic component in all systems. This is much more akin to the civil sector and there is much scope for some synergy. Just as the military will use civil technologies, so there is also huge potential for spin off from military technologies to the civil sector"

One aspect of the contribution of this study is that it will provide insights into the contemporary defence environment. The DUT2 phenomenon has not been intensively studied, and many studies are now several decades old. This study aims to update the frontier of knowledge in reaction to these changes. It would seem that these changes have affected the DUT2 phenomenon and increased its potential in some areas.

2.4 The defence sector institutional environment

Due to the large level of defence spending in the UK, the government can influence the size and structure of the UK's Defence Industrial Base (DIB) (Hartley et al., 1997). By means of Defence Industrial Strategy (Great Britain. Ministry of Defence, 2005) and subsequent publications (Defence Technology Strategy (Great Britain. Ministry of Defence, 2006) and Defence Technology Plan (Great Britain. Ministry of Defence, 2009)), the government also influences the set of technological capabilities retained onshore within the UK. In order to create a full set of military capabilities, the MOD can purchase additional military equipment from overseas markets. It would not be possible for the UK economy to support a full "cradle-to-grave" industrial capacity across all aspects of military capability, due to factors such as decreasing defence spending and increasing costs of the complex systems involved.

To achieve this would require a much larger economy. Therefore, international trade in defence equipment is likely to occur. In the UK, the volume of defence exports is significantly higher than imports, greatly benefitting the UK's trade balance. The UK is in fact one of the largest arms exporters in the world (Stockholm International Peace Research Institute, 2012). These markets create the opportunity for UK defence firms to increase their sales by exploiting these export markets through geographic diversification.

The government plays a three-fold role toward the DIB, being a customer, supporter of export efforts and controller of procurement policy (Hislop, 1997). In essence, they can influence the size of the market through their own purchases and setting of export regulations; and also have the ability to adapt the domestic institutional conditions under which the DIB operates (see Figure 3).

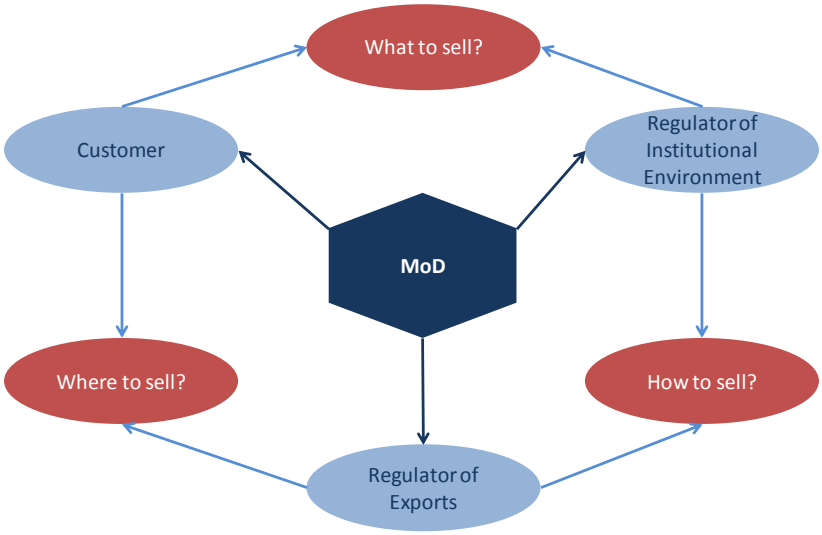

Figure 3: The three-fold role of the MOD (adapted from Hislop, 1997)

Alongside the sheer size of its military forces, a nation's defence capability relative to other nations can be measured in how many years technological advantage they possess in their front-line equipment (Middleton et al., 2006). In essence, a nation wishes to acquire a technological advantage, which can be measured in years, over any potential rivals in order to have the capability to successfully win battles while ensuring the minimum level of casualties. There is also a strong incentive to invest in technology in order to reduce manpower requirements and the associated rising costs. Middleton et al. (2006) show that gaining this technological advantage is a strategic interest for the MOD, and that this advantage is correlated to defence R&D spending. This shows that defence spending can be a source of innovation, and subsequently that there will be opportunities for technology developed in the defence context to diffuse into the civilian sector, as it is likely to be "cutting edge", and its development has been subsidised by defence spending.

The MOD is therefore incentivised to acquire cutting-edge technology, which may not be available on the open market. The MOD is also likely to be willing to pay a premium for this technological advantage, and also invest in the early stages of its development, in order to ensure that it can be successfully procured as mentioned in the previous section regarding the "cash-flow valley of death". In fact, early-stage R&D funding is often awarded on a cost-plus basis (Currie, 2011).

There are many examples of the UK and other nations' militaries having acquired cutting-edge technology, which is not likely to have been developed in civilian markets, at least not at that time. Some examples of novel technology include the jet engine, the Global Positioning System and the internet; which have all been applied in civilian sectors since their initial development in a military context. In addition, some military technologies have not transferred to civilian applications, there

are examples of a nation's attempt to gain a military advantage by possessing unique, cutting-edge technology, such as the Harrier jump-jet or stealth technology, without civilian applications.

Essentially, as the military is acting under a different incentive structure than profit-maximising firms in the wider economy, it is likely that the MOD and other defence agencies will invest in, and develop technology from which they gain a tangible advantage, but may not have been worthy of investment in a civilian context. This can constitute a source of innovation, which can diffuse into the wider economy. To better understand the DUT2 phenomenon, it is necessary to understand the factors, which influence defence procurement decisions. These are part of the MOD's overall strategy and therefore will shape the institutional forces and demand conditions to which defence contractors are exposed. Understanding this environment is key to identifying firm-level effects within defence contractors, which may potentially affect the transfer of technology.

There has been some academic attention to the institutional effects involved in military procurement. In particular, Eyre & Suchman (1992) provided an analysis of nations' procurement policies using four theoretical approaches. Their goal was to explain what equipment is procured. A fifth has since been added to this model (see Figure 4).

The first approach is the strategic-functional approach, which asserts that nation-level military strategic interests explain procurement outcomes. In essence, a nation will build a military capability in line with the strategic military intentions of the government. These are likely to be dependent on the procurement policies of neighbouring nations, as well as other nations, which are seen as competitors or threats. The nation's own strategic military ambitions will also affect procurement policy.

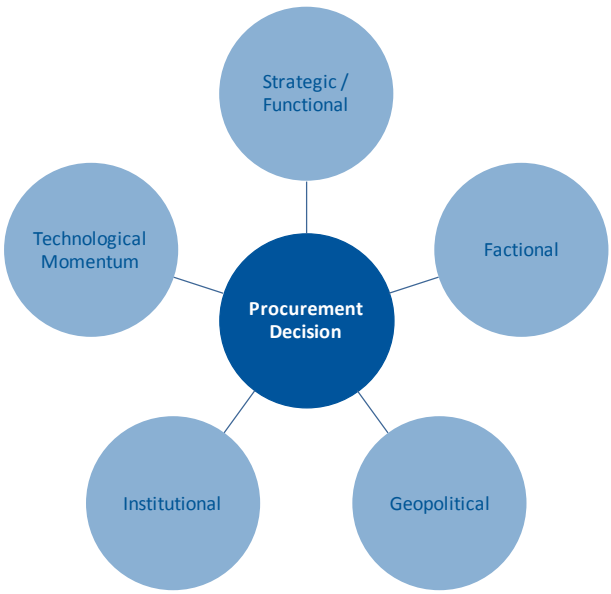

Figure 4: Factors influencing defence procurement (based on Eyre & Suchman, 1992)

The factional approach concentrates on competing internal political interests on a sub-national level. This suggests that procurement decisions are influenced by the actions of competing elements within the armed forces, i.e. the air force, navy and land forces. In particular in a time of increased pressures on military spending, each faction is likely to lobby to acquire the equipment it considers necessary and desirable. This effect has been identified in the recent Gray Report, a review on defence acquisition in the UK (Gray, 2009). Various factions within the MOD are likely to be in competition for resources. As there are increasing pressures on military spending, coupled with an increasing cost of weapons systems, this is inevitable. In fact, as most major procurement projects can be seen within the domain of a particular area of the armed forces (i.e. Astute class submarine & new Aircraft Carrier for the Royal Navy; Eurofighter for the RAF), this factional effect is likely to be a source of significant pressures within the defence sector, and is additionally affected by the fact that many individual decision-makers within the procurement process may have backgrounds in one of the armed forces.

The geopolitical approach considers regional military conflicts to be extensions of superpowers' global strategies. This approach is rooted in the Cold War era, and predicts nations' procurement strategies to be influenced by their alignment with these superpowers, i.e. the USA and the Soviet Union. Regional conflicts can then often be seen as "proxy fights" between these superpowers (Eyre & Suchman, 1992).

These three approaches are based on a logic of rational choice, with a nation's procurement policy seen as a rational response to its environment and own strategic ambitions. However, their fourth explanatory factor takes an institutional approach, at a global-political level of analysis where procurement policies can be explained not only by "the autonomous decision-making activity of independent nation-states, but rather the metonymical iconography of the global cultural order" (Eyre & Suchman, 1992, p.150). Therefore, a procurement policy might be influenced by institutional logics (Thornton & Ocasio, 1999) relating to the nation's government's perceived position in the global political order. This can be used to partially explain the high level of military capability possessed by the UK.

Since the end of the cold war, it has been argued that some elements of the UK's military capability, most notably an active nuclear deterrent, are far from cost-effective, as the threat of nuclear war with the Soviet Union has diminished. However, this institutional approach explains that certain pressures exist for the UK to maintain a nuclear deterrent. The UK is one of a small group of nations

possessing such a capability[2]. Giving this up would be seen as exiting this group of nations, therefore weakening the UK's position in the global order (Eyre & Suchman, 1992).

This model has can be complimented by a fifth factor, technological momentum (Hutton, 1995). This factor accounts for the government's aim so support the national DIB. Defence procurement can be used to increase the utilisation of manufacturing facilities, therefore increasing employment, for example. The utilisation of the national DIB also prevents this capability from atrophying. This can be driven by an industrial policy aimed at strengthening these capabilities, but also can result due to domestic political pressures, e.g. to prevent unemployment.

At the domestic-national level of analysis, i.e. the environment within which defence firms sell, the lens of institutional theory provides an effective tool to identify the forces affecting defence firms. The defence sector is subject to strong institutional forces, and therefore is a particularly good setting for the application of this theoretical framework. Specific coercive, normative and mimetic pressures act upon the organisations in the sector. These coercive, normative and mimetic pressures are rooted in the regulative, normative and cognitive institutional effects, respectively (Scott, 2001), and are heavily influenced by the MOD, due to its three-fold role.

Several government publications give insight into the pressures exerted on the firms within the industry. For example, the National Audit Office (NAO) and the MOD have released a document outlining how the MOD aims to use effective contracts to maximise the likelihood of successful project outcomes (Currie, 2011; Great Britain. National Audit Office, 2006). Within this framework, the MOD has adopted a "gold-standard", of effective relationships with suppliers in the context of a major procurement project. Defence firms are therefore encouraged to conform to MOD specific contracting requirements, transparency and standard practices of interaction and accounting (Currie, 2011; Gray, 2009), contributing to the sector-specific regulative and normative effects.

Other organisational documents, such as the Defence Industrial Strategy white paper (Great Britain. Ministry of Defence, 2005) and the Procurement Handbook (Great Britain. Ministry of Defence, 2004) signal to firms how they are expected to behave, organise themselves and interact with the MOD.

Most commonly, the MOD uses the CADMID (for products) / CADMIT (for services) life cycle including two 'gates' of approval (see Figure 5). It is of particular interest that the main gate is set relatively early in the development process, therefore the MOD takes on a high proportion of the

[2] The other nations known to, or believed to possess nuclear weapons are the USA, France, Russia, China, India, Pakistan, Israel and North Korea (Kile et al., 2009)

projects technological uncertainty and risk. In addition, the development phase up to this point is commonly funded by a cost-plus contractual arrangement.

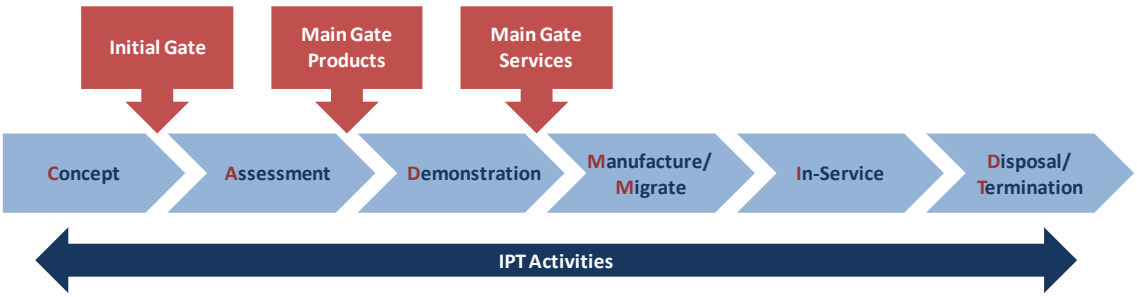

Figure 5: The CADMID / CADMIT process (Great Britain. Ministry of Defence, 2004)

An IPT is an Integrated Project Team (IPT), which is a team set up by the MOD to monitor the procurement process. Its members include technical experts, as well as management and contracting advisors. The IPT is set up in order to improve the efficiency of the procurement project, and to ensure that the project goals are achieved to the necessary levels quality and cost, and on time. The IPTs are in fact part of a larger framework applied to procurement decisions, namely the "Smart Acquisition" framework:

1	**Through Life Systems Approach**	applying Whole-Life-Costing techniques
2	**Integrated Project Teams**	Team including managers with core skills to complete acquisition cycle (incl. Support and termination/disposal)
3	**Industry Relationship**	effort towards a 'better, more open relationship'
4	**Investment Structure**	higher investments during early project stages
5	**Trade-Offs**	effective trade-offs between system performance, through-life-costs, and time
6	**New Procurement Approaches**	different procurement strategies
7	**Approval Process**	streamlined and efficient project approval

Figure 6: Smart Acquisition Framework (Great Britain. Ministry of Defence, 2004)

These processes indicate that the MOD is committed to taking a life-cycle approach to procurement, to counter the cost escalation issues which would occur in the case of a lack of forward planning and cost control. However, the Gray report (2009) shows that defence procurement is subject to a substantial degree of cost escalation, despite these efforts. This discrepancy indicates that although the MOD is aware of the lack of cost-focus in the defence industry, its attempts to counter this have not been as successful as desired.

Complex government procurement leads to the creation of incredibly complex supply chains involving a multitude of heterogeneous actors taking roles at varying points along the chain. For this reason it is very difficult to propose characteristics of all firms involved. However, an initial breakdown of the structure of the Defence Industry has been proposed by Hartley et al. (1997) and Hislop (1997) (see Figure 7). They propose a three-tier pyramidal structure, with the prime contractor at the apex of the pyramid. The second tier is made up of the major subcontractors, who provide major sub-systems, which are integrated by the prime contractor. Examples of these sub-systems include radars, navigation systems, engines, displays or radios. These are then built into the platforms which are created by the prime-contractors, hence the term "systems-integrators" often used to describe the firms at the apex of the pyramid.

These two tiers have attracted a large portion of research attention, as they can be more easily defined as defence contractors, as they produce high value-added products and services, which are directly aimed toward the military customer. However, the third tier is made up of the suppliers of individual components or materials to the first- and second-tier firms. There are significant methodological issues related with obtaining an effective sample of these companies, due to the complexities inherent to the complex defence supply chains. However, they are inherently important as they are likely to be more "Dual-Use" orientated, as their products and services are likely to be less focussed on the defence application, the further they are removed from the final complex system / platform delivered to the defence customer (Hartley et al., 1997).

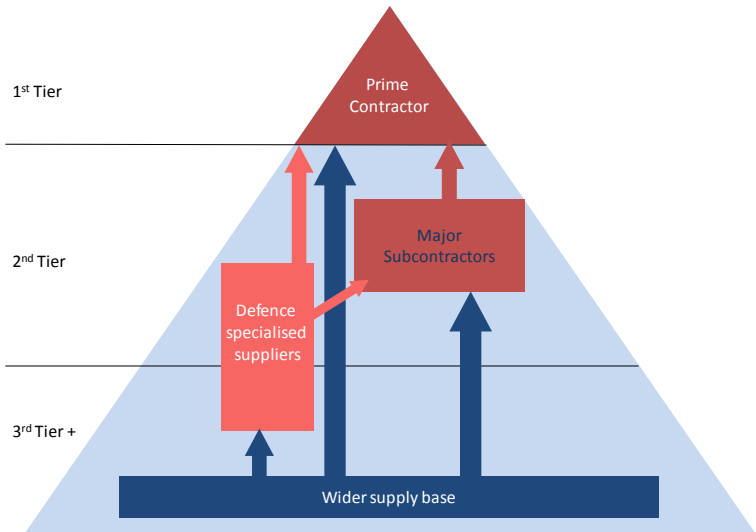

Figure 7: Three-tier pyramidal structure of defence suppliers (adapted from Hartley, 1997; Hislop, 1997)

This three-tier structure does however have its limitations. In particular, the third tier is likely to be a very complex construct of suppliers of heterogeneous products and services, with a range of relationships with each other, as well as with the first- and second tier firms. Due to the complexity

and cost of the final product, as well as the major subsystems, the upstream supply networks will include firms of varying degrees of technological intensity. There will also be product-specific technical demands, which will permeate the supply chain to these suppliers (Hislop, 1997).

For example, in an aerospace context, where weight minimisation is a significant factor, the supplier of components such as screws may be intensively incentivised to create high-value, lightweight, high performance screws, which will be integrated into subsystems such as the gearbox of a helicopter. However the same is not true for other applications, for example a maritime application, where more generic components may be applicable. Therefore the third-tier supplier of a specific component to aerospace may be subject to strong pressures to innovate, with the potential to earn significant revenues. The subsequent innovation can then potentially be leveraged to generate revenues in civilian sectors.

This "third-tier" therefore contains a heterogeneous mix of firms regarding defence sector focus, ranging from highly specialised high-technology component manufacturers to suppliers of generic products. In this context it is remarkable to note that suppliers to the defence industry often do not realise that they are part of a specific defence supply chain (Hartley et al., 1997). This is reflected in the nature of their business (e.g. Steel stockholders & distributors, suppliers of seals, gaskets, washers, adhesives etc.), but also in the fact many suppliers at this level are not specialised defence firms. In some cases this is due to the fact that their business is based on sales of commodities. This further underlines the fact that this "third-tier" of suppliers deserves additional research attention.

It is therefore useful to re-evaluate the structure suggested by Hislop (1997). Hartley et al. (1997) consider the second tier suppliers to be the direct suppliers to the prime-contractor. In this context they suggest a division in the second tier of the supply chain, with some firms falling into the group of sub-primes or "super" first level suppliers. This effectively indicates that the prime-contractor acquires complex sub-systems directly, but also a range of less sophisticated products and services in order to create the final product. However, the prime-contractor is able to acquire non-generic products and services, the adaptation of which may be essential for the final military application. Therefore the manufacturer of what may seemingly be a generic, "low-tech" product may hold a key technological capability within the supply chain for a complex government procurement project.

Due to the MOD's demand for cutting-edge high-technology products, it is likely that defence firms will develop specific technological capabilities. It is also clear that due to the high development costs, firms are likely to specialise on specific technological capabilities. It is not possible for an economy the size of the UK's to develop and maintain a full set of capabilities for the production and maintenance of a full repertoire of military capabilities, especially considering full life-cycle costs.

This specialisation, driven by the costs of developing effective sub-systems and platforms, leads to the DIB being a set of oligopolistic markets.

The prime contractor for a major complex defence procurement project can be seen as the focal point of the project's complex Supply Chain. Therefore they must have strong capabilities in the construction of the relevant platform, and the integration of various sophisticated sub-systems and components. In the example of a military aircraft, this would mean constructing the airframe, and integrating components such as engines, radar, navigation- and other avionics systems, etc.

Figure 8 shows a synthesis of the factors influencing MOD procurement decisions and the structure of the market. It can be seen that defence firms build specific, costly technological capabilities in order to meet the MOD's demands. They must also adapt their organisation and practices to the MOD's requirements and expectations. They are more likely to do this is if they have a high strategic focus on defence work. The prime contractor then integrates the various systems from the subcontractors and acts as the nexus between the MOD and the DIB. The prime contractor acts as a systems integrator, and also takes on significant management responsibility for the supply chain. Therefore, the prime contractor is more heavily exposed to the pressures to conform to the requirements and expectations of the MOD. The greater the focus of the firm on the defence sector, the stronger these forces are likely to be, therefore increasing the firm's level of adaptation to these defence sector-specific forces. Each DC*i* box in Figure 8 represents a defence firm or business unit possessing a well developed technological capability in the specific field. Two boxes with the same index *i* will be two distinct technological capabilities embedded within the same firm. Firms can possess more than one capability, and will compete within markets, which are made up of firms with such a capability. As these capabilities are costly and difficult to imitate, these markets will generally be oligopolistic in nature. Such a capability can be in the field of, for example, radar, airframes or aircraft engines. Only a small number of firms globally compete in such markets, as the capabilities are resource intensive and the associated skills, knowledge and systems very specialised.

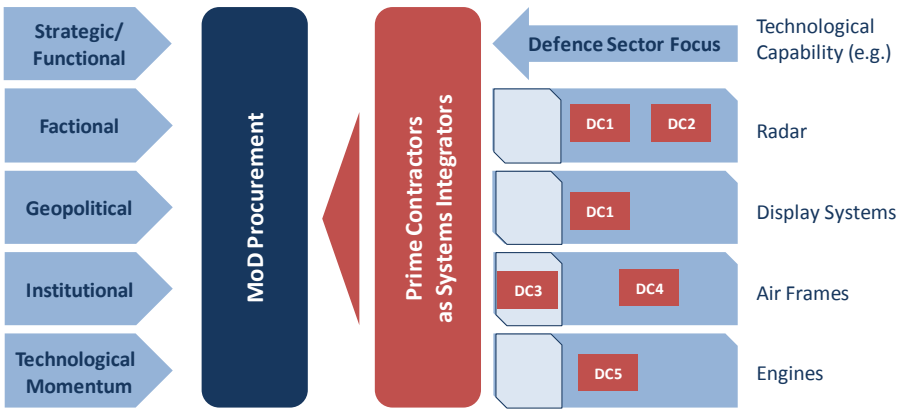

Figure 8: The defence sector procurement environment

This visualisation represents the structure of the industry at the prime contractor and major subcontractor level. The prime contractor is also likely to have some of the necessary technological capabilities, and may produce some of the subsystems itself. In the UK context, BAE Systems is the largest and most representative prime contractor. Smaller firms may act as prime contractors in the case of smaller projects. It is also not uncommon for the prime contractor to be a consortium of various defence firms, set up specifically in the context of a specific procurement project, in order to increase their chances of winning the contract, as complex procurement projects often necessitate a combination of technological capabilities.

These firms also draw upon the wider supply base of the economy; however, the greater the distance of a firm from the MOD, is likely to be associated with a lower strength of the institutional forces to which they are to be exposed. A lower level of exposure will then reduce their level of adaptation. The role and behaviour of the firms at these lower levels of the supply chain is significantly underexplored. However it is likely that these institutional forces will diffuse through the supply chain, and will be heavily influenced by how the prime contractor manages the chain, in its role as a nexus between the DIB and the MOD.

As stated above, the level of exposure to these forces will affect the level of adaptation of the firm to these forces. This overview has briefly outlined the environmental characteristics to which defence firms are exposed, in the UK context. These include specific and highly regulated procurement processes and contractual arrangements, as well as the institutional forces which are affected by the fact that the sector is rather insular, and procurer-dominated. The following section will provide more detail relating to the competitive dynamics in the industry, subject to the structures described above.

2.5 Dynamics of the defence industrial base

The contemporary defence industrial context has seen a high degree of supply chain rationalisation, leading to the development of supply chains consisting of a smaller number of suppliers, who are however more capable. The increasing complexity of the systems procured in the defence sector has greatly increased the difficulty for individual firms to possess the required capabilities to support the whole life cycle of a system. In this context, there is an inherent modularity within the supply chain, with specialised subcontractors developing subsystems, and adding more value by performing higher level assembly tasks, while the prime contractors develop their specialised systems integration capabilities, focusing on e.g. final assembly and after-sales services (Rebolledo & Nollet, 2011).

The concept of systems integration as a core capability of modern high tech firms has attracted attention in the academic literature (Hobday et al., 2005). The authors state that modern high technology firms are increasingly willing to outsource certain productive tasks in order to focus on the coordination of the complex supply chains necessary to manage the production of complex systems, and integrate an array of complex subsystems. They also follow the development of systems integration capabilities to the defence sector of the 1940s and 1950s. It is apparent that these developments are still ongoing in the defence sector and have far reaching effects on defence supply chains and their members.

Supply chain rationalisation and the development of more capable, specialised suppliers have led to the development of systems integration capabilities within these suppliers, particularly of major subsystems. These firms are expected to manage and coordinate their own supply chains, and are thus developing these sophisticated, specialised technological capabilities (Smith & Tranfield, 2005). Essentially, this focus on systems integration and effective supply chain management permeates from the prime contractors, indicating the complexity of the subsystems which are to be integrated within the context of a major defence contract.

Although driven by the systems-integrator prime contractors, a degree of the supply chain rationalisation has been realised by the sophisticated high-level subcontractors who have engaged in significant M&A activity, but also taken on liaison roles with SMEs at lower levels in the supply chains. The effects of this are significant for the prime contractors; for instance, Antill et al. (2001) refer to one major European prime contractor whose supply base had been reduced from 400 firms in 1997 to 25 in 2001. This can potentially increase the understanding which prime contractors have of their suppliers' capabilities, and can facilitate the involvement of suppliers at an earlier stage of the development process.

These factors have led to the establishment of complex supply chains which is characterised by the dispersal of knowledge within specialised firms, and by the principle of modular subcontracting. This has increased the dependency of prime contractors on such capable subcontractors, and has developed in the context of an increase in mutually beneficial partnering arrangements, and a move away from adversarial relationships. However, in order to compete as a subcontractor, a firm must first possess such valuable, rare capabilities, as well as organisational abilities necessary to integrate into such a complex supply chain, and generate appropriate interface capacities to enable modular subcontracting. At this point it is also imperative to recognize the gatekeeper role played by the prime contractors.

A strong consensus emerged from interviewees from various points in the defence industry regarding the supply chain management and coordination role of prime contractors, particularly their power. Despite initiatives such as the Centre for Defence Enterprise, which has the goal of increasing engagement of "non-traditional" suppliers in the defence industry, SMEs wishing to engage must often do so by first engaging with a prime contractor. In fact several interviewees referred in particular to the considerable power held by BAE Systems, due to its size and also its well established links to procurement agencies.

The opinions as to the benefits and drawbacks of this situation were not as unanimous. Some managers appreciated the organisational capabilities which large prime contractors bring to the relationship, e.g. in assisting in the contracting process and other administrative activities, which were particularly difficult for SMEs, particularly if they are not heavily focused on defence work. However, one senior SME manager stated:

> *"MoD-proper (i.e. DE&S, etc) won't deal with small companies directly & large defence primes are so slow & laborious that we would go bust before they had finalised any contract."*

Other respondents have stated that the institutional forces emanating from MOD and the government in general are in fact filtered by prime contractors, and the forces which then affect the suppliers can vary depending on which prime contractor they engage with. The role of the prime contractor is also interesting in this regard due to the fact that the prime contractor, in its gatekeeper role, represents the primary link between the primary buyer of complex systems, i.e. MOD, and the complex network of suppliers. In essence, MOD accesses the prime contractor's organisational capabilities necessary to procure these complex systems by granting them this privileged position. However, it is necessary stress the point that MOD itself may not have these capabilities in house, a point made by Antill et al. (2001):

> *"There is considerable academic and practical evidence that strategic purchasing and supply chain management is most effective when the buying organisation is able to work closely with a limited number of highly preferred suppliers. Smart Procurement reflects this but the Ministry of Defence cannot be classed as a purely commercial organisation as illustrated in the literature. It is in fact a bureaucratic organisation that finds the entrepreneurial culture difficult to assimilate"*

This underlines the potential for prime contractors to play an important role by leveraging their systems integration and supply chain management capabilities to improve the procurement outcomes of the MOD. However, this presents unique challenges for SMEs wishing to enter or remain in the industry. As mentioned, there has been a degree of consolidation in the form of M&A activity, but another phenomenon in the industry has been the creation of regional consortia, such as the North West Aerospace Alliance, the Northern Aerospace Industries, and the Midlands Aerospace Alliance. In fact, this coordination is also present at and beyond the national level, in the form of the A|D|S group, which represents the UK aerospace, defence, security and space industries in the UK and abroad. Add to these the Aerospace, Aviation and Defence Knowledge Transfer Network, and it becomes apparent that there is a considerable drive to enable communication and co-operation.

These networks create the potential for the discovery and assimilation of new technologies by leveraging the core and peripheral supply base. Therefore, there are efforts to support development and generate engagement at multiple levels of the supply chain. However, the fact remains that the industry is pyramid shaped and hierarchically structured, with high levels of concentration toward the apex of the pyramid.

Therefore, firms must be aware of their current and intended position in such a structure, while taking into account the changes both in market structure but also both in the advancement of technology, as well as the changing requirements of the customer. Recent government spending cuts however, are likely to induce a reaction from firms involved in the defence sector, potentially increasing the relative value of certain avenues of diversification. The recent pressures due to reduced spending however magnify pressures which were already previously extant.

The main routes for such diversification had been summarised by Antill et al. (2001) well in advance of the financial crisis:

> "- *Scope for diversification (related and non-related) into non-defence industry activity.*
>
> - *Scope for product development to increase areas of involvement within the defence sector*
>
> - *Defence sector exit strategies*

- *The need for strategic alliance / partnering agreements in order to maximise expertise and the opportunity to enter new markets in the case of contractor logistic support and facilities management".*

The fact that this correlates with current market conditions underlines the fact that these cost pressures are likely to accelerate an already initiated trend in the market.

Additionally, it is necessary to underline the potential to leverage strengths in exports as the defence industry has significant and growing customers in non-domestic markets, presenting firms with the following option:

- Scope to increase engagement in existing foreign markets, or enter new foreign markets

Traditionally, the competitive dynamics literature has focused on firm actions as outcomes of the competitive process. In the case of defence, with its pyramid structure and strong institutional forces emanating from a centralised buyer, presents the opportunity to expand this view to include the antecedents of such firm behaviour, to address the "why" question (Livengood & Reger, 2010).

Therefore, when looking at the DUT2 phenomenon, it is not only necessary to address the substantive barriers which may affect technology transfer, but also the cognitive, affective or other psychological factors. In essence, despite varying degrees of dependence on the defence industry in terms of revenues, it is likely that involvement in the industry is facilitated by costly strategic investment decisions to both offer valuable technology but also be capable of engaging with the relevant stakeholders and conforming to the complex regulatory and administrative regimes present in the industry. Increasing levels of embeddedness in such an environment is also likely to lead to cognitive barriers which pose an additional obstacle. However, defence budget reductions will lead to increased pressures for firms to diversify away from traditional business. The following section will outline certain paths available to defence firms in more detail. Defence firm diversification paths

The following section will outline a model based on the Ansoff matrix (Ansoff, 1957), but specifically targeted at the options which are available to firms with a defence focus regarding diversification.

This model is based on DUT2 from defence to non-defence applications, and is focused on the diversification away from defence activities. In essence, it is based on an initial status quo of developing technology for defence purposes and selling it into traditional defence markets. In the UK context, the traditional market can be seen as the UK domestic "home" market.

The two-dimensional model consists of four boxes with the Y-axis plotting geographic diversification, and the X-axis diversification away from defence applications (Figure 9). In the graph, the bottom left

box consists of the abovementioned status quo: Selling to UK MOD based on the technological capabilities on which the firm's competitive advantage is built. Based on this model, firms can diversify by selling defence equipment into foreign markets, or by diversifying out of defence and leverage existing technological capabilities in non-defence markets. It is of course possible to combine these two approaches, and also to retain original activities alongside new ventures. There are numerous potential driving forces for such moves; however in the current climate opinion would seem to suggest that there is likely to be a reduction in UK defence spending in the coming years. In such a situation, defence firms with distinct technological capabilities are likely to be incentivised to leverage these capabilities in other markets. Nevertheless, either route is beset with challenges to firms wishing to engage in these diversification processes.

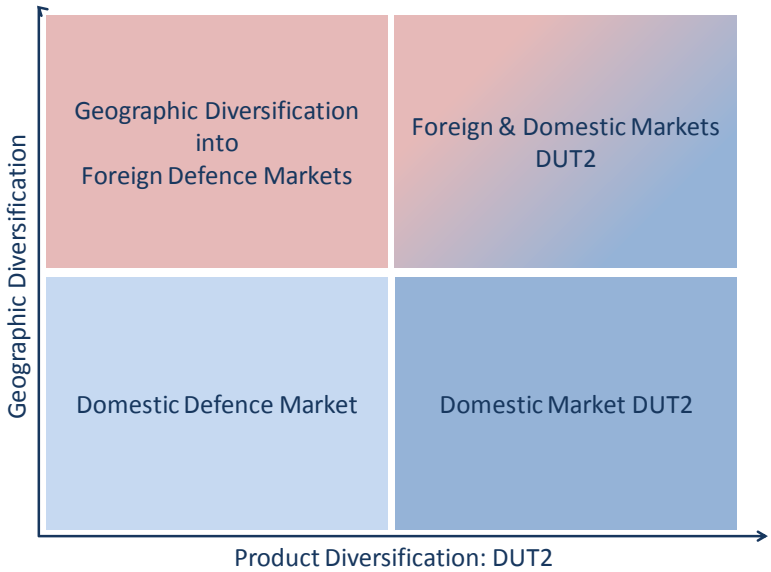

Figure 9: Defence firm diversification paths matrix (adapted from Ansoff, 1957)

Any defence firm wishing to pursue a strategy of geographic diversification must be aware of several strong barriers and significant challenges. Export regulations set in place by home market governments have some academic attention, and are in fact a major constituent of the original definition of the concept of Dual Use Technologies (Parkhe, 1998). Governments are strongly incentivised to control the diffusion of technologies for two reasons: 1) these technologies may be used to nefarious ends or be otherwise dangerous in the possession of unsanctioned parties; and 2) the spread of such technologies may weaken the strategic interests of the home nation (either by eliminating a comparative military advantage or by furnishing a party with a military capability).

The larger UK defence firms have been taking measures to "hedge their bets" geographically. For instance, BAE systems reports that it currently operates out of five home markets: the UK, the US, Saudi Arabia, Australia and India (BAE, n.d.). Interestingly, they also report that they have marginally

more employees in the US (39,200 employees) than in the UK (38,400 employees) (BAE, n.d.). It can in fact be argued that BAE is becoming an increasingly "American" company.

BAE, QinetiQ, Rolls-Royce and Babcock International[3], among many others, have been expanding through foreign acquisitions (Currie, 2011). Such acquisitions can be an effective market entry method, as it can be used to circumvent barriers to entry, i.e. regulatory and political challenges.

Additionally, many global defence firms are refocusing on other markets, such as Brazil, Turkey and South-East Asia, for which the industry expects significant growth in the future. In fact, Thales' CEO states in an interview that Thales has "embarked upon a transformation of [the] organisation worldwide. The future growth [he sees] in the rest of the world, as [one] should bear in mind that in total the world defence market is still going up at a two-figures growth per year." When asked which countries he will envisage to be the "biggest spenders" in the coming years he replied: "Asia, where [Thales] continue[s] to invest, Brazil, Russia [and] India. In fact, the defence spending goes along with the economic growth." (ReutersVideo, 2011, 0:36-1:10).

Firms wishing to leverage their technologies in non-defence markets are faced with an array of challenges, which will be a significant focus of this thesis. It is very likely that the changes in defence procurement strategy since the end of the Cold War have increased the potential for DUT2, due to the higher level of electronic components, and the rapid acquisition and insertion of novel technologies (for instance the significant focus on creating strong networks between military assets, utilising communications, navigation, sensors, command and control and other electronic- and computer-based technologies). This coupled with the changing position and role of the DIB in the modern world creates a range of opportunities, but also challenges in this context.

In summary, this model has captured the main options open to a defence firm, if either confronted by decreasing revenues in domestic defence markets, or if aspiring to grow when faced with stagnant defence revenues.

2.6 Industrial context conclusion

In conclusion, the UK defence sector is highly complex and subject to unique institutional forces that influence not only the structure of the market, but also the organisational structure and practices of firms operating in the market. The Government acts as a customer, a supporter of export efforts and as a controller of procurement policy, hence heavily influencing the nature of the sector as well as

[3] These are mentioned as ranking under the top 10 UK MOD suppliers (Currie, 2011)

the size of the market. As a customer and supporter of export efforts to favour the trade balance, the MOD provides a significant commercial opportunity due to the scale of spending on the procurement of technology, its research, development and maturation and often represents an early adopter of technology. In fact, it invests in technology, even at early stages with high uncertainty, on a cost-plus basis, creating a source of innovation with the opportunity to diffuse in civilian markets. These investments, especially at early stages are often only possible in this context, as they would prove unattractive in civilian markets due to the high degree of uncertainty and simply the required capital expenditure. This is possible since the government acts upon a logic of rational choice rather than profit maximisation, with the goal to build and maximise capabilities on the basis of strategic ambitions and as a response to its environment. In this context, as the government seeks a position in the global political order, procurement decisions are highly influenced by other nations' capabilities.

In order to achieve this position of technological advantage, the government is willing to provide large scale budgets for specific customised products and systems, willing to pay a premium for technological advantages, often leading to cost escalation despite efforts to control cost with different measures aiming to maximise the likelihood of successful project outcomes. Despite the willingness to provide large scale budgets, the MOD is increasingly subject to significant budget cuts, while labour and technology costs constantly increase.

These factors lead to significant regulatory measures directed at suppliers, who need to adapt their organisational practices and standards and need to respond to the MOD's unique specifications and requirements. The closer a firm operates to the MOD, the higher the strength of institutional forces (regulative, normative and cognitive) that act upon the firm creating coercive, normative and mimetic pressures. This leads firms in the sector to conformity, which increases with stronger technological focus. The technological focus of a defence firm is not only dependent on the specific and costly technological capabilities that the MOD demands, but also on the position of the firm within the industry, i.e. whether the firm is a prime contractor (1st tier), a major subcontractor (2nd tier) or an individual component/material supplier (3rd tier), and the position in often highly complex project supply chains. Given that 1st tier suppliers are highly specialised and anchored in defence technological capabilities, working close to the MOD, these firms are subject to such strong institutional forces, such that their organisational structure, their practices and cognitive characteristics are strongly affected. However, it is important to note that the nature of military systems has significantly changed due to the end of the cold war and the emergence of intricate electronic technologies. During the cold war, governments demanded large mechanical weapons, for which other applications outside of defence would have been highly unlikely. The increasing need for

electronic components and telecommunications increases the likelihood of application in civilian markets, thus enhancing the transferability of technology. However, diversification into other markets is still likely to be difficult for firms strongly embedded in the sector due to the adaptation of organisational structures, procedures and cognitive patterns characteristic to the sector. While geographic diversification may be less difficult as other nations' defence markets may be similar to the domestic market, export regulations may inhibit the effort to geographic diversification. Furthermore, diversification into other markets, namely civilian markets, maybe more difficult for defence firms due to the very different nature of the market and the customers' needs as well as the possibly large number of customers. Logically, civilian market firms may also encounter difficulties entering the defence market due to the lack of experience with the requirements and institutional environment of the defence sector.

The following theory section will begin with a review of the DUT2 literature, focusing on micro-level DUT2. This literature identifies several factors, which affect the likelihood and success of DUT2, at project level, firm level and contextual levels. Many of these factors are related to the idiosyncratic defence sector-specific forces to which defence firms are subjected. The literature review section serves to review existing knowledge, and to move closer to the development of testable hypotheses. Continuing from the literature review, the main theoretical constructs underlying the study will be described. As this study focuses on a complex phenomenon in an idiosyncratic context, the study employs a methodological combination of exploratory field work and empirical quantitative work. To this end, theory development was built around interviews with industry experts, in an iterative process designed to ensure validity of constructs to be operationalised, as well as to enable the capture of the complexity and richness of the factors involved.

3 Theory

3.1 Micro-level Dual-Use Technology Transfer literature review

This review intends to synthesise the literature on spill-overs at the micro level, from the defence sector to the wider civilian economy. It seeks to identify which conditions affect the likelihood, as well as the outcomes of such spill-overs. The organisational level factors and contextual factors affecting these spill-overs will be identified, by reviewing the literature specifically on the DUT2 phenomenon at the micro-level. As this literature is considerably less extensive than the related macro-level literature (Hartley, 2006), other sources which specifically assess the specific characteristics of defence firms in general will also be used to compliment the review. The fact that the literature at the micro-level is not extensive has been addressed by macro-level researchers, and in a review of the macro-level literature, Hartley (2006) specifically addresses this gap in the literature. The macro-literature is noteworthy in its inconclusiveness, and therefore effective micro-level studies would be valuable beyond the scope of this level of analysis, in particular because these spill-overs occur at the micro-level.

In order to begin an exploration of the concept of DUT2, it is necessary to demarcate the field and to specifically address the concept of technology. Several definitions of technology are available in the literature, and can be seen as existing along a continuum, ranging from a very narrow definition restricting the term to products and artefacts, to a far more broad definition including the social relations and mode of production in which the development and production of artefacts occurs (Galtung, 1979; Molas-Gallart, 1997). Here we use the following definition for technology: "Technology comprises the ability to recognise technical problems, the ability to develop new concepts and tangible solutions to technical problems, the concepts and tangibles developed to solve technical problems, and the ability to exploit the concepts and tangibles in an effective way" (Autio & Laamanen, 1995, p. 647).

Molas-Gallart (1997) builds on Autio's and Laamanen's (1995) definition and includes "capital equipment, software, scientific and technical knowledge, skills, research and production processes, designs, blueprints, management techniques and principles, and the resulting products developed to solve technical problems" (Molas-Gallart, 1997 p.369).

In this project we define Dual-Use technologies as technologies with current or potential military and civilian applications, the definition adopted by Molas-Gallart (1997).

One main goal of this study is to identify the firm-level factors which influence the likelihood and success of DUT2. It is however necessary to also take into account technology- and project-specific factors. To this end it is necessary to outline the likely effects of technology attributes on DUT2

Technology complexity has been extensively studied in the context of strategy and technology studies. The defence sector has been a particularly salient context for such studies, as defence agencies procure highly complex and costly weapons systems, which are often highly technologically sophisticated. This has led to a number of studies focusing on e.g. aircraft carriers (Roberts, 1990), or tanks (Demchak, 1992).

Technology complexity increases the difficulty of acquiring and maintaining the requisite capabilities to construct components, but also integrate these into complex systems. High technology complexity also increases the organisational costs of commercialising technologies, leading to difficulties in such commercialisation projects (Hagedoorn, 1993; Langlois & Everitt, 1992).

Singh (1997) defines a complex technology as "an applied system whose components have multiple interactions and constitute a non-decomposable whole". These characteristics of systemicity, multiple interactions and non-decomposability lead to complex technologies being constituted of components which are likely to be highly complementary or in fact co-specialised (Teece, 1986).

These attributes and their implications according to Teece (1986) would seem to depict a negative correlation between complexity and *modularity*, i.e. complexity, including multiplicity of interactions and non-decomposability lead to a difficulty in decomposition and recombination of modules without losing system functionality. In fact the concepts of "near decomposability" (Simon, 1962) and "loose coupling" (Weick & Orton, 1990) had previously been used to describe the strength of such structural dependencies (Campagnolo & Camuffo, 2010).

The concept of *modularity* is of great concern in the defence industry, at various levels of analysis. Prime contractors as systems integrators must manage complex supply chains in which subcontractors supply technologically sophisticated and complex components. To this end, the challenge of integration of these systems involves significant investment in the interfaces between these components. Although individual components, such as radios, radar systems or communications equipment may have potential for DUT2, this potential will be affected by the degree of co-specialisation with respect to the components of a system. Stringent military specifications and the requirement of integration within complex systems can pose a barrier to DUT2.

Additionally, there is a high demand for integration of various military platforms and systems into higher-level networks which constitute military capabilities. In fact, the continuing focus on C4ISTAR and the integration of various military platforms serves to make the point that modularity can be viewed from varying perspectives.

What becomes apparent is that modularity is a relative attribute, and is dependent on the unit of analysis. The potential for transfer of an individual module, i.e. component or subsystem, will be dependent on the ability to decouple it from the wider system, as well its level of specialisation.

The central hypotheses of this research relate to the suggestion that organisational factors specific to defence firms negatively influence the likelihood and success of spill-overs from the defence industry to civilian industries. Taking an institutional approach, it is suggested that firms operating within the defence sector, and subject to the defence procurement process, will be subject to specific isomorphic pressures and institutional norms, which have an effect on the cognitive framework of these firms. This cognitive framework is likely to be inappropriate in the context of any attempts to operate outside the defence sector.

In line with the lens of the capabilities literature, defence firms are also likely to develop highly-optimised, defence-specific capabilities in order to meet the idiosyncratic needs of the industry, and the MOD's requirements as the dominating buyer. These capabilities may function as rigidities if the defence firm seeks to diversify into civilian markets.

To this end, we search the literature for insights into the nature of the idiosyncrasies of the defence industry, and their effects on the firms operating within the sector. Various authors have addressed specific factors, which affect the likelihood of spill-overs into the civilian economy on a micro-level. Other authors have identified defence-specific attributes, which are likely to affect DUT2, but have pursued research agendas focussing on other issues, such as the efficiency of the sector. However, these studies can also give rise to insights in the context of this research.

Several authors have looked at the impact of export controls on the US and other countries' Military-Industrial-Complexes (Parkhe, 1992; Elder, 1992; Fuhrmann, 2008). This particular research topic raises an important point for the DUT2 researcher – the intended meaning of the term "Dual-Use". There is a body of literature concerned with this topic, but more heavily focussed on the dangers of the diffusion of technologies which have legitimate civilian applications, but could be used in a military context, the so-called "dual-use dilemma" (Atlas & Reppy, 2005). In the past the term "dual-purpose" has also been used. During the Cold War in particular, this issue was of current interest,

and has influenced policy as can be seen for example in the 1977 U.N. Report on the Economic and Social Consequences of the Arms Race and Military Expenditures, which asserts:

> *"problems arise when technologies are applicable both for military purposes and for important civilian ends (. . .) for such dual-purpose technologies attempts to control the arms race, not by abolishing weapons systems but by confining their possession to a limited set of countries, will inevitably come into conflict with the aim of making existing technology available to all countries in a non-discriminatory manner".* (quoted in Molas-Gallart, 1997, from Krieger, 1981, p. 13)

Traditionally the emphasis was on proliferation of nuclear technologies, but more recently includes the diffusion of technologies involved in the field of biological warfare (McLeish & Nightingale, 2007; Atlas & Reppy, 2005).

Molas-Gallart (1997) argues that the emphasis has shifted from the focus on arms control to a more industrial view concerned with the exploitation of R&D and manufacturing outcomes beyond initial goals. However a review of the literature reveals significant gaps in research in the field. Gummett (1990) asserts that defence science and technology policy are under-studied, especially in relation to the level of defence R&D spending, and points out that previous literature on economic and sociological factors, and their impact on defence and technology policy were unsatisfactory.

Due to the importance of the topic on the one hand, and the changes in the competitive environment for the defence industry on the other, subsequent research has been conducted in the area, however this has often been fraught with the data problems, i.e. problems of measurement of defence R&D, regarding data sources, interpretation and comparison across national borders (Molas-Gallart, 1999). These aspects present the opportunity to undertake an up-to-date study of the field, using both a case study approach as well as a survey of a large population of UK defence firms, as well as other secondary sources in order to attain a degree of triangulation, and make a substantial and rigorous empirical contribution to the understanding of this important phenomenon.

Molas-Gallart (1997) also identifies three main trends, which have driven the emergence of Dual-Use policies. These trends are (i) The decline in defence expenditures, (ii) The persistent growth in the cost of developing and procuring new arms systems and (iii) The changing relationship between military and civilian technologies. These trends have led to the increased promotion of dual-use policies, and at the firm level they incentivise diversification into non-defence markets.

Regarding point (i), the end of the Cold War led to a reduction in defence spending and size of armed forces (Hartley, 2006), however considerable defence expenditure on the conflicts in Iraq and Afghanistan counteracted this trend to a certain extent, which is reflected in an increase in spending

in real terms, despite a decrease in the defence expenditure as share of GDP (see Figure 10 and Figure 11).

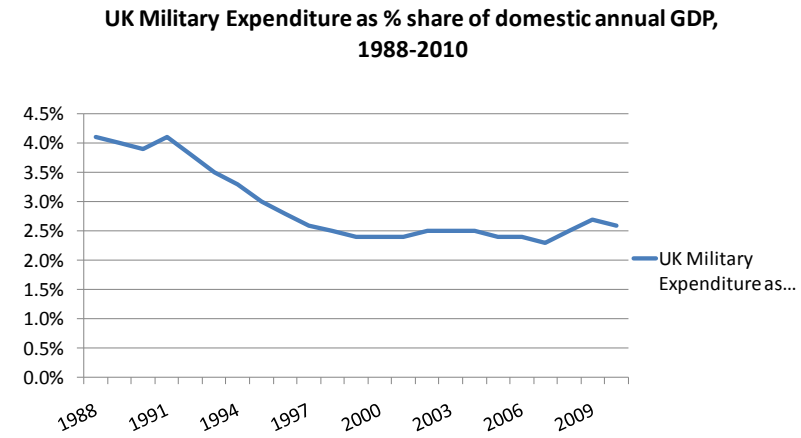

Figure 10: UK military expenditure as % share of domestic annual GDP 1988-2010 (Stockholm International Peace Research Institute, 2011)

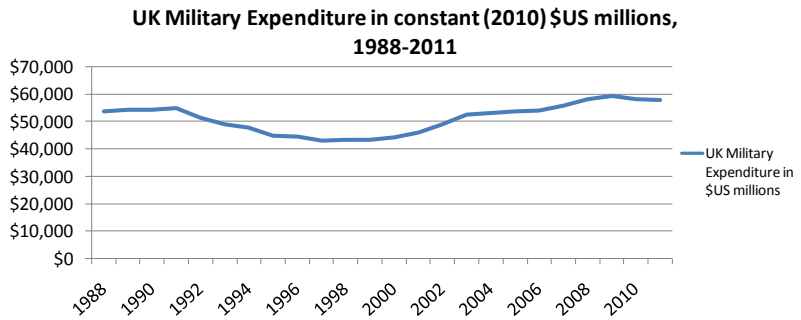

Figure 11: UK military expenditure in constant (2010) $US millions, 1988-2011 (Stockholm International Peace Research Institute, 2011)

Over the same time period, the costs of defence equipment and personnel have been increasing. Equipment costs have been rising by ca. 10% per year, whereas personnel costs have risen faster than wages in the civilian sector, due to the fact that UK has an all-volunteer force, which must be compensated for the disadvantages of military service (Hartley, 2006).

Points (i) and (ii) constitute the "defence economics problem", which leads to the MOD having to reduce the number of weapons systems it acquires, and make difficult choices in an uncertain

military environment. This has contributed to the third trend (iii), whereby, in terms of technology transfer, there has been a gradual shift from an initial logic of spin-off to the wider economy, to one of spin-in, where the defence sector is concerned with broadening its industrial and R&D base (Avadikyan & Cohendet, 2009).

Dual Use has often been advocated as a policy to maintain military capability particularly in the presence of government spending cuts. In the early 1990's, the defence industry was in transition from the Cold War era to a more modern defence industry. At this time the Dual Use concept attracted significant academic and political attention, particularly in the US (e.g. Round, 1993; U.S. Department of Defence, 1992; Gansler, 1989). In particular as a strategy to ensure the survival of a broad and capable on-shore defence industry, to ensure the potential for surges in production, and to justify defence spending by citing the benefits to the wider economy. Although interest in this particular avenue of research has declined, the current difficulties experienced by the financial crisis are likely to instigate renewed interest in the Dual Use phenomenon.

The majority of authors in this stream of literature assume the existence of a division between military and economic sectors, leading to differing business practices and creating a barrier to the transfer of technology between defence and other sectors. Often these barriers are cited as being principally organisational or administrative in nature, rather than relating to the technologies themselves (U.S. Department of Defence, 1992). This underlines the need to reinvestigate the firm-level factors which may be influential in such cases. There has been a general consensus that operating simultaneously in defence and civilian markets is extremely challenging. However, the last 20 years have brought about significant changes in the challenges the armed forces face, as well as in the defence industry itself.

Cronberg (1994) shows that the "traditional" military domain is changing and that the military is in fact losing its privileged position. Reduced military expenditure has weakened many defence contractors' positions and has driven them to seek alternative opportunities in civilian markets. Principally, this is driven by a more competitive approach to procurement which is being pursued by defence agencies, as well as increasing international competition. Exacerbating this effect, innovative firms are refraining from taking military work, citing complicated military accounting requirements, IPR issues and highly detailed specifications. These specifications have often been so specific as to greatly inhibit the contractor's "interpretive flexibility" (Cronberg, 1994).

Round (1993) also notes that even at the time of writing, there was a great deal of convergence in the strategic R&D focus between the military and the wider economy. In fact, during this time the US Congress requested lists of critical technologies from both the DoD and the Department of

Commerce (DoC). Of the 21 technologies listed by DoD, only five do not appear on the DoC list. It is likely that this trend has continued, due to more recent changes in strategic goals in defence procurement.

At this point it is necessary to focus more closely on the nature of dual use technologies, and to describe the landscape in which they exist.

What are Dual-Use Technologies?

Following Molas-Gallart (1997), we define Dual Use technologies as technologies with current or potential applications in military and civilian sectors. However, to capture the richness of the concept it is imperative to view the dual use concept as a continuum, with various technologies having differing potentials for dual use and applications having varying similarities between sectors. Intuitively, it can be argued that application similarity has a strong effect on the likelihood of transfer across sectors. For instance, strong technological developments in the civilian semiconductor industry, and the development of computer systems has led to the increased procurement of "off-the-shelf" or slightly modified computer systems by defence agencies. However, to procure a fighter aircraft or warship, these agencies must turn to a more specialised industrial base.

In this context, Molas-Gallart makes a distinction between Dual-Use outputs and inputs. These outputs can be products, but also codified knowledge or management principles, techniques and systems. The inputs on the other hand can be either fixed capital in the form of production or research facilities, or labour, in the form of skills and know-how (Molas-Gallart, 1997) (see Table 1).

Inputs	Outputs
• Fixed Capital	• Products • Services
• Labour	• Management Principles, Techniques & Systems

Table 1: Dual-use inputs and outputs (Molas-Gallart, 1997)

Dual-Use Technology Transfer

In this project we substantially build on the work of Molas-Gallart, and adopt his definition of DUT2. Molas-Gallart (1997, p. 372) defines the concept as "a special instance of technology transfer across applications that takes place when a dual-use technology developed for a military (or civilian) use is transferred to a civilian (or military) application."

Whereas in general, technology transfer can refer to the transfer of technology between economic units or applications, in the case of DUT2 there must be a transfer from an original military application to a civilian application (or vice-versa). This becomes important when considering the broader literature on technology transfer. The transfer of technology between nations, from universities to industry or from research to production, have all attracted significant research attention, however, the necessity for the transfer to a different application is a distinctive trait of DUT2.

Additionally, DUT2 does not necessarily involve the physical or geographical relocation of technologies. It is entirely plausible for a firm to diversify and reallocate its resources within an existing plant, and achieve a DUT2 outcome (Molas-Gallart, 1998).

Focusing on the applications enables the emphasis on the differing requirements, specification and other potential expectations which may or may not be significantly different in the defence context than in the wider economy. For instance, military equipment deployed in the field is likely to have strict requirements for ruggedness and reliability, or potentially more technical requirements such as having a low electromagnetic signature in stealth applications. Such equipment may in principle however be based on technologies which have significant potential for applications in civilian markets.

DUT2 Mechanisms

Molas-Gallart (1997) suggests a typology of DUT2 mechanisms, with four types of DUT2, differentiated by whether they are straight or adaptational in nature. This difference regards whether the transfer mechanism encompasses the adaptation by the transferor of the technology to its new applications. Also, the typology makes a distinction between internal transfer within a single unit, and transfer between two or more units.

Examples of Dual-Use products which are applicable with little or no modification are e.g. steel and generic computers, as opposed to those which require significant adaptation (e.g. Radar), and finally those which were designed for several uses from inception (e.g. transport aircraft, helicopters).

The subsequent two-by-two matrix is then used to classify the various mechanisms of DUT2, as can be seen in Table 2. This paper contributes to the field in that it clearly demonstrates that adaptational transfer is associated with a higher level of risk, due to the increased levels of technological uncertainty involved in the further development of the technology to meet the needs of the intended civilian application. However, it presents these two modes as a dichotomous distinction between straight transfer and adaptational transfer. Therefore, the introduction of scale variables to capture the level of required adaptation and customisation would be of great value.

Mode / Actions	No Adaptation	Adaptation
Transfer internal to a single unit	Internal straight transfer	• Dual-produce & integration • Conversion • Diversification • Vertical repositioning
Transfer between ≥2 units	• Technology Brokers • Improving communication • Internally-led commercialisation • Publications • User facilities	• Spin-off companies • Collaborative Partnerships: - Cooperative R&D programmes - Joint Centres - Direct finance of DU - R&D

Table 2: Dual-use technology transfer mechanisms (Molas-Gallart, 1997)

Internal straight transfer refers to DUT2 within a single business unit, where a technology originating in e.g. defence is utilised in a non-defence application. This is often the case if a firm maintains a central database of technologies, which can then later be used to exploit new market opportunities.

This is also the case if a firm sells a “commercial off the shelf” (COTS) product to a defence agency, or another defence supplier further downstream. This approach will generally be associated with lower risk, as the firm does not engage in the adaptation of the technology, and it is not dependent on any interfirm relationships other than between buyer and seller.

Internal adaptational transfer efforts involve internal processes within the firm aimed at adapting the technology to enable its application in a new market. This can be a challenging process, as the adaptation process can bring with it technological and market risk, particularly in the case of entry into a new market. In the case of defence to non-defence technology transfer, this is likely to involve the move from engagement with a small number of customers, with which the firm has developed long-term relationships, to the engagement with a more heterogeneous population of customers

which are culturally different. The required marketing and other organisational capabilities for this switch may not be present within the firm, posing significant challenges.

External straight transfer is another option for firms, and involves relatively low risk, but enables the firm to extract value from technology without engaging in the adaptation process themselves. By hiring technology brokers, or by creating a similar internal brokerage, firms may be able to generate e.g. licensing income by essentially selling the rights to their technology-based intellectual property.

However, selling the rights to use technologies in such a manner can give rise to additional challenges, particularly if the exploitation of the technology requires tacit knowledge which is not transferred to the transferee. The development of complex technology within a firm is very likely to be dependent on the tacit knowledge possessed by technical staff, and the challenges in technology transfer in such cases have been documented in the literature (Molas-Gallart, 1998), and also confirmed in interviews.

Several networks exist within the defence industry and beyond aimed at improving communication channels regarding the availability of-, and demand for technologies. For instance, the Technology Strategy Board (TSB) has set up a number of Knowledge Transfer Networks (KTNs), to facilitate the exchange of technology within various domains, e.g. the Aerospace, Aviation and Defence KTN. The defence industry is also characterised by well developed regional trade associations, as well as the former Defence Manufacturers Association, now part of the A|D|S Group.

External adaptational transfer is perhaps the most challenging option in organisational terms. It can involve the creation of collaborative partnerships between firms, a phenomenon which seem to be becoming more common in the defence industry. However, such partnerships require substantial commitment and trust, and the management of IPR and other legal concerns. There is a broad literature regarding interfirm alliances, highlighting motivations such as gaining access to capabilities, other resources, or new markets (Hagedoorn, 1993). If we assume that firms heavily reliant on defence sales are exposed to strong sector-specific institutional forces, and adapt accordingly to this environment, this access may prove valuable; however success in such relationships is not guaranteed.

Similarities in technological domains between firms have been shown to enhance the ability to learn from partners (Lane & Lubatkin, 1998). Also, Cohen & Levinthal (1990) show that R&D investments can improve a firm's ability to internalise knowledge acquired from partners. As the development of knowledge is subject to path-dependency, we can assume that prior knowledge will affect the ability to acquire and assimilate knowledge in the future. In this case there may be considerable differences

in knowledge relating to the applications of technologies, as well as pertaining to the technologies themselves. Essentially, this mode of DUT2 poses considerable barriers to firms, particularly if they are engaging with firms which may possess potentially valuable capabilities, but have developed dissimilar knowledge due to their prior involvement (or lack thereof) in the defence sector.

Spin-off companies also embody a mechanism of external adaptational transfer. The phenomenon has been studied in the context of government- and university spin-offs. This path provides the potential to extract value from technologies while compartmentalising the risk within the spin-off firm, which can be set-up specifically for the commercialisation of the technology. As such, it can be a manifestation of the parent firm's unwillingness to perform the necessary adaptation in-house, either due to a lack of the requisite capabilities or a poor strategic fit.

This typology is interesting since it represents an attempt to frame the study of DUT2 mechanisms, which is something that has not often been attempted. Alic et al. (1992) suggest eight different forms of relationships between military and civilian technologies; however their approach is not intended to focus on the technology transfer process in particular.

Another contribution of the typology is to highlight the richness of the DUT2 concept, in that there are many mechanisms which can be employed. Combined with the heterogeneity of technologies, and the differing competitive pressures to which firms are exposed to at different levels of defence sector supply chains, it is apparent that this complex phenomenon cannot be dealt with in a "broad-brush" manner. The review of the literature points to the fact that the area is understudied, for instance, Kulve & Smit (2003) state that the previous literature has "no unequivocal concept" of Dual-Use technology development, due to differing industrial contexts.

More attention has been paid to the factors which may act as barriers DUT2, often taking a policy-level perspective and reviewing various legal and regulatory developments. These studies mostly focus on a single factor in isolation. However, some insights can be gained from this literature, as it also addresses firm-level effects and strategies to overcome these barriers.

Barriers to DUT2

Many examples of the process of adaptation from military to civilian use show that the process can be very long and difficult. The cases of Boeing-Vertol and Grumman[4] in the 1960's and 70's show that major defence contractors can face severe difficulties when attempting to apply their capabilities to serve civilian markets (Molas-Gallart, 1997). The causes of these problems are said to be similar to problems affecting large defence systems contracts, namely *high costs*, *quality deficiencies* and *scheduling problems*. In the civilian commercial environment these can amount to insurmountable barriers to success.

Other problems of operating in defence markets as well as civilian markets are addressed by Cronberg (1994). The first of these problems is stated to be the differing cultures in traditional military and civilian domains, where the former is far less cost-driven, with the emphasis being on equipment quality and a "performance at any cost" culture (Cronberg, 1994). The second is described as the "way military firms are organised and the networks in which they are embedded", i.e. close client relations and the common occurrence of products being sold before they are produced. The third difference is said to be "psychological", with military managers, scientists and workers often showing different behavioural patterns and opinions regarding their place within society, compared to their counterparts in civilian industry.

In addition to this, Molas-Gallart & Sinclair (1999, p. 663) cite a study undertaken by Reppy (1994) of the US nuclear weapons laboratories attempts to transfer technology to commercial users, and offers the following list of obstacles:

> "
> • *Large bureaucracies linked to military-funded work and slow to downgrade their military work and establish new links with potential commercial clients*
> • *Pervasive security classification*
> • *Unfamiliarity with the needs and constraints of private industry*
> • *Technical staff preference to work on complex, high-profile projects*
> • *The trend to cast laboratory projects in terms of grand challenges rather than the more mundane problem of solving commercial work (Reppy, 1994, p.53)."*

[4] Boeing-Vertol was involved in the rail passenger carriage industry; Grumman attempted to move 50% of their sales to commercial products such as buses, refrigerators, solar energy, canoes and incinerators (Markusen & Yudken, 1992 p.214)

As stated above, Cronberg (1994) argues that innovative firms are refraining from taking military work, due to complicated military accounting requirements, IPR issues and highly detailed specifications, inhibiting the contractor's "interpretive flexibility". It is likely that this effect will also be applicable in the other direction, as defence contractors will be highly adapted to this very different environment and may not have the capabilities to deal with a high degree of interpretive flexibility.

Indeed, the fact that products are often sold before they are produced, and that defence contractors bid for procurement contracts which include highly detailed specifications, removes the need for organisational skills relating to marketing in the traditional sense. The lack of selective pressure to develop such skills within the defence sector can therefore represent a great disadvantage when attempting to diversify into civilian commercial markets.

In addition to having strict specifications, military customers may also have security and control demands, such as in the realm of data management and sharing in collaborative civil-military satellite observation (Cervino et al., 2003). This case, involving a joint French-Italian programme, actually illustrates a shifting of control to the military, who gained priority access after they became involved in a project, which was initially planned to be civilian-led.

The concern over control regarding the benefits of a project has also been addressed in other work. Bellais & Guichard (2006) addressed this problem with respect to Intellectual Property Rights (IPR). They argue that an effective IPR framework could act as an incentive to civilian-military collaboration, and that the contract design is crucial. Often, spin-offs will fail due to security reasons; however, parts or processes of the programme in question could be used commercially without harming strategic superiority. This control issue is likely to be dependent on the nature of the technology, its strategic importance and its potential to be used for malevolent purposes (e.g. nuclear- and biological technologies). This element of the effect of the nature of the technology on the likelihood and success of DUT2 has not been fully explored.

The technologies in question may also not be market ready, and therefore may involve considerable further development cost. This is related to the concept of adaptational transfer (Molas-Gallart, 1997), and does address the issue that these increasing costs may be encountered to a varying degree depending on the specific project, however this article focuses mainly on the effect this has in relation to IPR.

Increased costs will further increase commercial firms' demand for sufficient control over the benefits to justify their investment, as they seek to justify the risks they are subjected to. Bellais &

Guichard (2006) go on to suggest the following proposals for strategies to foster a market for defence-born technology:

- Revealing adequate information about innovations and technology
- Determining the right perimeter for patents or other means of protecting intellectual property
- Reducing uncertainty about contractual terms between the state and its industrial partners
- Setting up mechanisms to facilitate the development of civilian applications

These points indicate that there may be a degree of information asymmetry, whereby organisations wishing to commercialise defence-funded technology may not be aware of the existence of a potential for DUT2, or the necessary mechanisms to achieve successful commercialisation.

Stowsky (2004) shows that Military R&D projects performed in an isolated environment result in inferiority in price and quality for dual-use technologies compared to the products supplied by commercial markets. The distinction is made between *Shielded Innovation* and *Shared Innovation*. The traditional military approach of Shielded Innovation has led to a competitive disadvantage for American businesses, as foreign competitors are allowed to develop their own technologies over time, whereas the US firms may have been able to establish themselves in these markets before the foreign competitors had developed them. This relates to the concept of the "Wall of Separation" (Markusen & Yudken, 1992, p.69), which is in essence the concept that there exists a degree of division of the defence industry from the wider civilian economy, which brings about "a business culture on the military side that is ill suited to engage in commercial production, and vice versa".

The concept of the Wall of Separation is however not universally accepted. One opposing view was introduced by Kelly & Watkins (1995). They oppose the view of Markusen and Yudken (1992) that "subcontractors have become more, rather than less specialized in military projects, as the 'wall of separation' reaches down into their ranks". They counter by stating that commercial-military integration is in fact common within the US machining-intensive durable goods (MDG) sector.

This study is one of few to provide quantitative empirical evidence in this context, however, it must be noted that the sample in this case was a very broad sample of 973 plants involved in the MDG sector. Most previous studies had focused more heavily on the defence sector involvement of firms; however, some analyses of individual defence supply chains had looked further upstream. (e.g. Hartley et al., 1997).

Kelly and Watkins found that the vast majority of these firms were not heavily specialised for defence work, and that commercial-military integration is in fact common. This does not disprove other work which has shown that the further away from MOD, the weaker the institutional forces will become, and the lower the level of specialisation will become, on average (Hartley et al., 1997). However, I contend that the true nature of the wall of separation is that its effect can be plotted on a continuum from the Markusen & Yudken concept as one extreme, and the Kelly & Watkins concept on the other.

By conducting a large scale quantitative analysis I believe it is possible that the true picture is characterised by the existence of a subset of firms within the supply base which is more exposed to the defence sector-specific institutional forces. Toward the apex of the pyramid, these forces are likely to produce cognitive, structural and procedural and idiosyncrasies within firms with a heavy defence focus. This will then lead to rigidities in the firm, should it wish to engage in other markets. This would fall in line with the concept of "identity domains", wherein a firm's perceived identity will affect its awareness of other opportunities, the motivation to pursue them and the suitability of the firm's capabilities for such an endeavour (Livengood and Reger, 2010).

A great deal of the literature pertaining to DUT2 has focused on changes in the defence industry after the end of the Cold War. It is likely that the modern defence industry is subject to a far weaker "Wall of Separation", due factors described in section 2. Some authors have concentrated on firm level factors which facilitate overcoming the barrier between defence and non-defence sectors.

The resulting economic disadvantage of the Wall of Separation is also potentially mirrored in a disadvantage in a nation's defence technology base. Kulve & Smit (2003) argue that Dual-Use can be a solution to this problem, by improving the technological base. They assert that the two forces dominating interactions between civil and military actors are (i) the availability of funding and expertise, and (ii) awareness of the potential duality. The fact that this awareness has been identified as a factor reinforces the concept of the wall of separation. However this concept of awareness must be complimented with a view of the cognitive framework within the defence sector – defence firms may not value such projects, even if they are aware of the potential duality, as it does not fit with their defence-specific identity.

Kulve & Smit (2003) have taken an innovation networks approach to the DUT2 process and highlighted the complex nature of interactions between actors. Several kinds of actors are identified: The civilian actors, military actors and dual actors; but also gateway actors, dedicated network builders and other critical actors. These may all play a role in the network, and must all be considered. In essence, research into the phenomenon cannot be exclusively focussed on the

transferor and transferee, as contextual factors as well as third parties play a role in the process. These actors can be created through policy-level decisions, in order to enhance the performance of a nation's R&D base, in response to the changes in the relationship between military and civilian actors in the economy. However more work is required to identify these other parties. Government agencies have been shown to be involved, however the actions of the defence firms involved, and their perception and responses to these developments requires further study.

If the forces stated above (availability of funding and expertise; awareness of potential duality) are not sufficiently strong, the social-technical networks within the industry tend to lend themselves to *concurrent technology development*, rather than *joint technology development* (Kulve & Smit, 2003). The former implies integrated development with parallel but distinct civilian and military projects, which, although connected by mutual interactions, do not imply integrated development and co-operation on one specific project. This concept approaches that of Shielded Innovation, whereas *joint technology development*, a deliberate degradation of the wall of separation, is similar to the concept of Shared Innovation (Stowsky, 2004). The recommendation is to develop "dual-capacity networks" to foster joint technology development. However, the authors point out that such "technology push-over" may have little positive effect on civilian utility, and may be implemented as it is seen as good defence policy (Kulve & Smit, 2003).

Cowan & Foray (1995) add to the complexity by introducing a time dimension into their analysis. They state the need to pay attention to the life cycle of the technology in question, pointing out that different types of learning are necessary at different stages in the life cycle. They also assert that the nature of the technology, in particular if it is a process or a product technology, will change the relationship between the military and civilian sectors. They argue that duality is likely to be beneficial early in the technological life cycle, as more extensive and diverse approaches to learning about the particular technology can be lucrative. Process technologies can also benefit later in the technology life cycle, as the spread of this learning can lead to rationalisation between the activities of civilian and military actors, provided sufficient similarity in needs and standards.

However, in many fields of interest to the DUT2 researcher, it can be extremely difficult to differentiate between process and product technologies, as is the case in advanced materials, where the materials scientist approaches a product development process often by designing a novel integrated manufacturing process (US Congress, Office of Technology Assessment, 1988). Also, the generalisation that the scope for duality is greater in process technologies can be met with numerous examples, as some product-oriented development programmes and subsequent complex systems do offer substantial scope for duality. For instance, the technological similarity between ballistic missiles

and civilian space launch vehicles is substantial. The development of high-bypass aircraft engines, which are commonly used in civilian aviation, was originally a military project as part of the development of the C-5A military transport aircraft[5] (Molas-Gallart, 1997).

Dowdall (2004) shows that defence suppliers now often have a diversified product portfolio in which the defence industry is only one of many sources of revenue. In addition, this paper demonstrates that analysis of the defence industry must also include an international dimension. The increased internationalisation amongst industrial actors, coupled with the increase in cost and complexities in projects greatly enhance the breadth and depth of the UK defence industrial supply system.

This review has demonstrated that there is a body of pre-existing knowledge pertaining to the potential barriers to DUT2, as well as other factors influencing the likelihood and success of DUT2 projects. Broadly, these can be separated into cognitive/cultural effects and procedural effects. The cognitive effects are based on the assumption that there is a specific defence sector identity, which affects defence sector employees as well as organisations. The procedural effects however refer to specific attributes of the procedures, practices and organisational structures of defence firms.

These insights will be used in the formulation of a model in order to predict DUT2 likelihood and success. It will be valuable to ascertain the relative importance of the defence sector identity and the resulting practices, procedures, and also the capabilities, which are constructed within this context. The model will be complimented with additional constructs relating to the maturity of the technology which is to be transferred – i.e. how much of the R&D process has been funded by defence agency investment. Also, the contextual factors of market similarity and the requirement for customisation will be included. Market similarity refers to the degree of difference between the target market and the defence industry. The requirement for customisation refers to the required level of customisation necessary to transpose the technology to the civilian application.

Table 3 gives a brief overview of many of the articles which contribute to the identification of factors which may influence the likelihood and success of DUT2. This is followed by the development of the theoretical models predicting DUT2.

[5] 55% of the initial R&D costs for their development were contributed by the US Department of Defense (Mowery and Rosenberg, 1982), cited in Molas-Gallart (1997)

Table 3: Literature review summary of factors affecting DUT2

Study	Factors	Factor classification	Methods
Bellais & Guichard, 2006	Effective IPR frameworks	IPR	
	Effective security control frameworks	Security	
Cervino et al., 2003	Defence firm's security and control demands regarding sharing and collaboration	Security	Literature synthesis & case study
Cowen & Foray, 1995	Duality more likely to be beneficial at early stages of technological life cycle	Technology	Development of conceptual framework based on literature synthesis
	Given similar standards and needs, process technologies can benefit later in technology life cycle since spread of acquired learning during the life cycle can lead to rationalisation between activities of military and civilian actors	Technology	
Cronberg, 1994	Defence firm staff's psychological, i.e. behavioural patterns and opinions	Cognitive	Literature Synthesis
	Differing cultures in military and civilian markets	Cultural/Cognitive	
	Defence firm's Organisational structure and network structure embeddedness	Organisational	
	Innovative civilian firms refrain from military projects due to complicated military accounting requirements, IPR constraints and highly detailed specifications	Project specific requirements	
Kulve & Smit, 2003	Lack of funding, expertise and awareness of potential duality lead to concurrent rather than joint technology development	Policy & Knowledge	Interview-based Case Study testing literature synthesis
	Awareness of potential duality of technology	Knowledge	
	Development of "dual capacity networks" to degrade the wall of separation and enable joint technology development, but may not increase civilian utility	Cognitive	
	Availability of funding and expertise	Policy	
	Complexity of network interaction between different actors in the network affects DUT2 as not only transferor and transferee are essential but also contextual factors and third parties such as policy-makers	Contextual	
Markusen & Yudken, 1992	Wall of Separation leads to differing cultures,being "ill suited to engage in commercial production" (both directions of DUT2)	Cultural/Cognitive	

Table 3 continued: Literature review summary of factors affecting DUT2

Study	Factors	Factor classification	Methods
Molas-Gallart & Sinclair, 1999	Staff preference to work on complex, high-profile projects	Cognitive	Qualitative analysis of semi-structured interview based case study
	Defence firm's organisational Inertia	Organisational	
	Defence firm's unfamiliarity with civilian industry's needs and constraints	Organisational	
	Defence firm products' pervasive security classification	Security	
Molas-Gallart, 1997	Information asymmetry between defence and civilian firms in regards to potential technological suitability for DUT2 application	Information asymmetry	Conceptualisation of DUT2 based on synthesis of literature
	Effective IPR frameworks	IPR	
	Increasing commerical firm's demand for control in terms of IPR as costs rise, to justify risks, especially when product has low market readiness	IPR	
	Adequate provision of information about innovation and technology	Knowledge	
	Defence firm's cost structure	Organisational	
	Reduction of uncertainty about contractual terms between the state and its industrial partners	policy-level	
	Defence firm's Scheduling Problems	Organisational	
	Set-up of mechanisms to facilitate the development of civilian applications by the state	policy-level	
	Defence products' market readiness (adaptational transfer)	Product specific requirements	
	Products' quality deficiencies to serve civilian and defence markets	Product specific requirements / quality	
Reppy, 1994	Defence firm's Tendency to cast laboratory projects in favour of more mundane commerical projects	Cognitive	
Stowsky, 2004	Shielded Innovation leads to competitive disadvantage	Organisational	
	Shared innovation as a deliberate degradation of the wall of separation	Cognitive	
	Defence-born products are inferior in price and quality for dual-use technologies compared to those directly supplied by commercial markets	Product-specific	

3.2 Factors influencing the likelihood of DUT2

The following section is related to two models predicting the likelihood of a firm having engaged in DUT2 from defence to non-defence and vice versa. These firm-level independent variables were operationalised in a survey instrument which will be described in the following chapter. The two models have a high degree of symmetry, which is mirrored in the development of hypotheses, however there are several key differences which are highlighted in this section.

3.2.1 Defence sector-specific organisational identity and DUT2

This section deals with the relationship between the strength of an organisation's defence sector-specific identity and the likelihood that the organisation has engaged in DUT2 from defence to non-defence and vice versa. Firstly, the direct relationship between identity and DUT2 will be presented. Then, the relationship between an organisation's technology orientation and DUT2 will be described. Subsequently, the interaction between these two predictors will be addressed.

Firms engaging in DUT2 are effectively redeploying their technological capabilities in new markets. The capabilities literature describes the capability – performance relationship in a rather generic manner, i.e. the presence of a capability leads to performance (Teece, 2007). Some authors have identified effects which moderate this relationship. For example, Slater et al. 2006 demonstrate that strategic orientation can moderate the capability – performance relationship, essentially stating that there must be a match.

The concept of identity has not often been explored in the context of firm capabilities. However, there is a body of literature linking identity to learning (Kogut & Zander, 1996), which reveals that identity affects what will be learnt. There is an opportunity to close a gap in the literature by bridging the identity and capability literatures.

The following section will link organisational identity to the capability – performance relationship. I suggest that organisational identity affects the deployment of capabilities, i.e. capabilities must be deployed to lead to performance, and identity moderates this deployment.

The defence industry and DUT2 in particular present a particularly salient context in which to explore this phenomenon.

Albert & Whetten (1985) first defined the concept of organisational identity as the features of an organisation, which are deemed by its members to be most central, distinctive and enduring. Here, we specifically use a social constructivist approach, which describes "the members' consensual understanding of 'who we are as an organisation'" (Nag et al., 2007, p. 824). In this view, the components of endurance and distinctiveness may be less stringent than in Albert & Whetten's original definition, however, they are still crucial to an organisations survival and growth (Gioia et al., 2000; Glynn, 2000).

Taking the view that organisational identity is more than a metaphorical device suggesting a resemblance between individual characteristics and the characteristics of a collective, we adopt the view that organisational identity is "a phenomenon experienced by organisational members, perceived by outsiders, and central to social processes with real outcomes in organisational contexts" (Corley et al., 2006, p.89). Therefore the collective level organisational identity is distinct from individual identity, however it is conceptually related.

However, as the organisational identity is an attribute of the collective of individuals, it is in fact grounded in the concept of social identity[6]. In this sense, many organisational behaviours are driven by this identity, as it provides a basis for e.g. "leadership, group motivation, communication and indeed organisation itself" (Cornelissen et al., 2007, p. S5). In essence, the cognitive categorisation processes within individuals lead to collective activities and processes.

Further, Cornelissen et al. (2007, p. S5) state that:

> "once a particular organisational identity has become salient for a particular organisational group and once the particular norms and values associated with that identity have been internalized, then that identity not only structures the psychology of individuals (e.g. their beliefs, attitudes and intentions) but also allows that psychology to be translated into the structures and products (e.g. the plans and visions, goods and services, practices and institutions) that are material building blocks of organisational life."

Drawing on this, it is central to my conception of identity that it is "more than a metaphor as it can be defined and measured as a distinct psychological construct that plays a specific role in organisational behaviour" (Haslam et al., 2003, p. 359). Equally crucial is that we refer to social (collective) identity, not a personal one. (ibid.).

The socially constructed nature of identity, based on the concept of *social identity*, is often treated as a different – although closely related – concept, to organisational behaviour. Organisational

[6] Social identity theory (Tajfel & Turner, 1979) and self-categorisation theory (Turner et al., 1987, 1994)

behaviour is conceived as an organisational-level phenomenon, which is distinct from the individual- and collective levels of analysis. At this level, organisational identity can be seen as a cognitive frame (Dutton & Dukerich, 1991), or a perceptual lens (Fiol, 2002), i.e. a self-representation which is "generally embedded in deeply ingrained and hidden assumptions" (Fiol & Huff, 1992, p. 278). Additionally, the identity can be manifested in language, i.e. firm names and narratives within the firm (Glynn & Abzug, 2002). These complex organisation-level constructs, and their meanings may not be directly apparent to the individuals within the firms, as they may be seen as a part of the intrinsic nature of the organisation.

Therefore, we suggest at this point that organisational identity can be viewed as an emergent phenomenon of a complex system of actors within the firm, affected by a complex institutional environment external to the firm. This complex structure then leads to behaviours which can be explained with the theory of social identity and self-categorisation, however, certain higher level, i.e. distinctively organisational-level behaviours, cannot be seen as a function of the "sum of the system's parts", but are uniquely characteristic of the *system*.

The link between collective agency and organisational identity is in fact crucial to the understanding of the effects of organisational identity on observed firm behaviour. As firm-level organisational behaviour is rooted in the collective agency implied by social identity theory, it is imperative to view the concept of organisational identity as a complex adaptive system of organisational members (i.e. a social system of "real people"). As these members themselves possess skills, attitudes and personalities, the organisation is a system composed of individual components, which in themselves can be seen as demonstrating complex, emergent behaviour. Therefore the firm can be seen as an aggregation of complex individual components bound by an array of heterogeneous connections – which lends itself to the conception of the organisation as a complex adaptive system.

Therefore, the organisational identity is built upon inputs from its members, however can drive behaviour which is not immediately explainable by analysing the individual members. In addition, organisational identity feeds back into the individual attitudes and behaviours of organisational members, creating a dynamic feedback loop. This aspect accounts for the relaxation of the endurance characteristic of identity proposed by Albert & Whetten (1985).

We suggest that the organisational identity can be seen as a lens, through which intended actions by firm management passes on course for the external environment. The "refractive index" of this lens can then affect the outcomes of actions initiated by the firm's management, potentially in unexpected or at least unplanned ways (Figure 12).

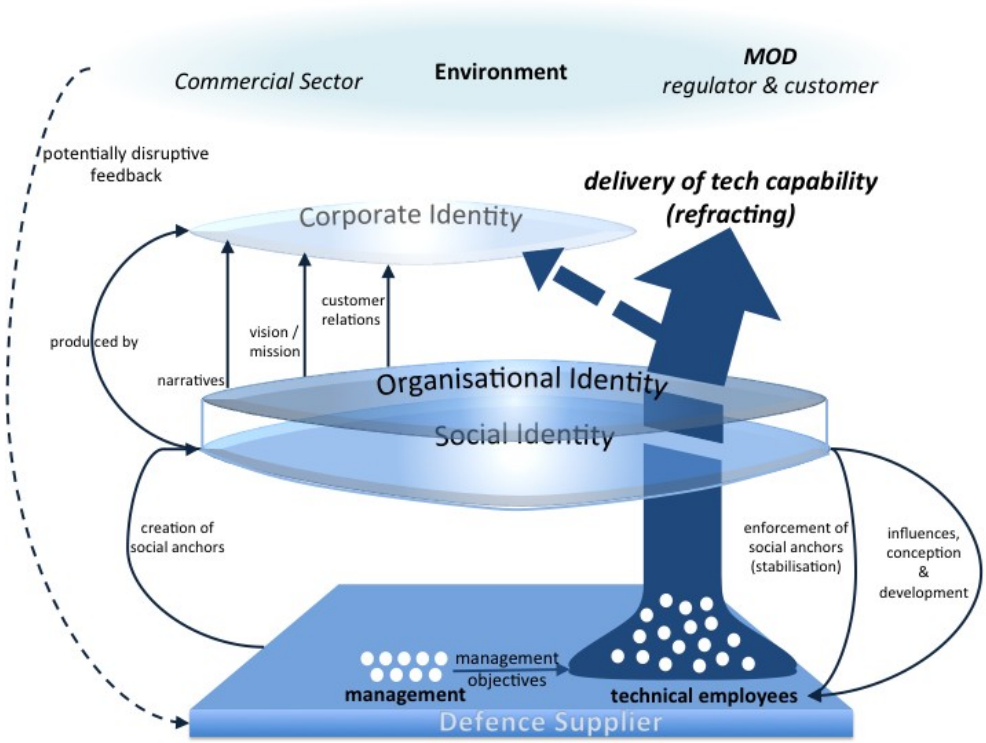

Figure 12: Social identity theory of technological capability delivery

Yolles et al. (2011, p. 644) state that "a collective agency may behave independently from the individual agents that compose it because the normative anchors for social behaviour may be different from the anchors of individual agent behaviour". They go on to note fact that this is supported by literatures on strategic groups (Fiegenbaum & Thomas, 1995), herding (Hirshleifer & Teoh, 2003; Welch, 2000) and Groupthink (Janis, 1972).

The above demonstrates that organisational behaviour can be conceptualised as a system level phenomenon, with attributes which are directly traceable to individual level actions and attitudes, however with an additional set of system-level, potentially emergent attributes which are not under the direct control of organisational members.

Following the assumption that the system, and the organisational identity, are both affected by and affect the cognitive frameworks of individual members, it can be assumed that each individual can have an effect on organisational identity. The effect of an average individual will of course diminish as the number of members grows. However, it is highly likely that more senior members of the organisation (i.e. senior management and board members) will exert a greater influence. This can be conceptualised with respect to the power distribution among organisational members, as more powerful members will have greater influence on the direction the organisation takes.

Following Livengood & Reger (2010, p.51), the beliefs held by executives as to the fundamental nature of their organisation, i.e. "'who' they are as a firm, 'what' they stand for and 'why' they are successful [Hambrick & Mason, 1984; Kimberly, 1979; Reger, Mullane, Gustavson & DeMarie, 1994]", are likely to become closely aligned with the system-level identity, as the beliefs of these top managers will be more closely related to firm-level actions than the beliefs of other members, in part due to the abovementioned power dynamics.

Selznick (1957) had already argued that the self-definition of the members within an organisation affects the organisation's distinctive competences. The central, distinctive and enduring components of the organisation's identity will then impact decisions regarding the top management's "theory of action", i.e. where and how the firm will compete (Livengood & Reger, 2010; Barney et al., 1998). Further, this will impact on the acquisition and maintenance of organisational resources, as these, especially knowledge, skills and expertise, are likely to be influenced by the underlying assumptions associated with beliefs in "who we are" as an organisation (Nag et al., 2007; Kogut & Zander, 1996; Oliver, 1991).

These underlying assumptions constitute the cognitive aspects of organisational identity. The cognitive aspects also underlie behavioural and subsequent structural manifestations of organisational identity. Corley and Gioia (2004) found that there is a distinct behavioural element to identity, as they showed that changes to organisational identity are associated with changes in behaviour among the organisation's members. Dutton & Dukerich (1991) found that identity is associated with the organisational routines, skills and decision-making processes within an organisation. Nag et al. (2007, p. 841) demonstrate that "the ways in which the organisation members […] used knowledge in their work practices affected and were affected by their collective notion of who they were as an organisation".

Livengood and Reger (2010) introduce the concept of identity domains, whereby some "external, competitive environments are also viewed by managers as more central, distinctive and enduring arenas where competitive actions and reactions carry greater psychological consequences for the very definition of the firm" (Livengood & Reger, 2010, p. 49). These domains can be constructed around economically important markets, geographical markets, or particular products and services. This concept addresses the issue that firms' identities are not just constructed internally, but also in reaction to the actions of their perceived competitors and other stakeholders.

In this context, identity can be decomposed into components. Previous research has shown that some organisations can have dual or multiple identities, and describe the management implications for navigating the complex environment this creates. However, we suggest that an identity in itself

can be constituted of distinctive "traits". We suggest that in the context of this study, the alignment of an organisation with the defence industry-specific identity domain can be seen as a distinctive trait. This concept of identity domains, and the application of this model to the DUT2 context, will be elucidated in the next section.

3.2.2 Defence industry identity and the defence industrial identity domain

In this study, we focus on the transfer of technology between defence and other markets. There are many anecdotal tales of technologies being developed in the defence industry, and then diffusing into the wider economy. Many of these technologies were developed within the defence industry as defence agencies often act as early adopters of new technologies, and are willing to contribute to the development costs of such technologies. In fact, there are significant institutional forces extant within the DIB, which is heavily influenced by the MOD.

These institutional forces and sometimes idiosyncratic market forces, as well as the perceived isolation of the defence industry from the wider economy, characterise the defence industry, and are often a significant factor in defence firm's perception of their identity domain. In fact, these institutional forces are likely to have an isomorphic effect on any firms involved in the industry, and this isomorphism is likely to be more pronounced the stronger the firm's strategic focus on the industry.

The effects of these forces are often manifested in certain structural, behavioural and cognitive logics within defence firms. As the concept of identity domain operates at the firm level, i.e. each firm constructs its own domain, we suggest that the stronger a firm's self-definition as a member of this exclusive group, the stronger these structural, behavioural and cognitive logics will be present within the firm. Further, as these logics are developed and maintained within the defence sector context, they are likely to inhibit the firm's awareness, motivation and capabilities regarding non-defence opportunities (Livengood & Reger, 2010).

In this context, firms are likely to generate cognitive representations of action-outcome relationships specific to the environmental conditions within their identity domain. Therefore the stronger a firm's defence sector-specific identity, the stronger their beliefs will be regarding the behaviours and structures required to achieve success. Combined with the lock-in associated with strong institutional forces, past success in defence markets is likely to have a reinforcing effect on these beliefs, leading to a path-dependent development of such cognitive representations.

The following tables (Table 4, Table 5, and Table 6) provide a brief overview of several articles relating to the concept of organisational identity:

Authors	Main Theme	Research Setting	Data Collection	Data Analysis	Main Results
Clark et al., 2010	organisational identity change during a merger of two rival organisations, "transitional identity"	2 American healthcare organisations	33 interviews (in two top management teams), observation, archival data	grounded-theory-building	identification of a "transitional identity" as critical to organisational identity change
Clegg et al., 2007	Identity formation in emerging industries, temporal and spatial strategies and resources as means to create organisational identity	Australian business coaching industry	53 firms surveyed, 11 interviews (company principals)	grounded-theory-building	spatial and temporal dimensions as part of the organisational identity construct
Corley, 2004	identity differentiation based on hierarchy level	spin-off from a global technology service provider (Fortune 100 company organisational unit)	38 interviews (managers), archival data, observation over more than 6 months (pre-, during-, and post-spin-off)	grounded-theory-building	Higher levels of the hierarchy see identity in light of the firm's strategy,lower ones in relation to the firm's culture
Corley & Gioia, 2004	process of organisational identity change	spin-off from a global technology service provider (Fortune 100 company organisational unit)	38 interviews (managers), archival data, observation over more than 6 months (pre-, during-, and post-spin-off)	grounded-theory-building	Model of identity change through a state of collective identity ambiguity as a process during identity change
Corley et al., 2006	Review of the theoretical concept of organisational identity, definition of the concept and particular aspects of identity and future research suggestions	Body of Literature on Organisational Identity	Body of literature	Literature review	Definition of organisational identity
Cornelissen et al., 2007	Integration of social, organisational and corporate identity into the concept of collective identity	Bodies of Literature on social, organisational, and corporate Identity	Bodies of Literature	Literature review and synthesis of corporate, social and organisational identity	Synthesis of corporate, social and organisational identity literatures and definition of requirements for the integration of macro- and micro-level analyses
Dukerich et al., 2002	Attractiveness of perceived organisational identity, construed external image,strength of system identification and cooperative behaviours	1,504 physicians surveyed in 3 different not-for-ptofit health systems including focus groups, additionally one-year follow-up of 285 physicians	survey with some longitudinal dimension	statistical analysis incl. factor analysis, structural equation modelling	Positive relationship of attractiveness of perceived identity and construed external image to physicians' identification with the system. Positive relationship between this identification and cooperative behaviour
Dutton & Dukerich, 1991	Influence of organisational identity and construed image on issue management	Municipal transportation company (Port Authorities of New York & New Jersey)	25 open-end-interviews (employees) over 9 months, internal and external archival data	grounded-theory-building	Construct of organisational identity and image linked to impression management and organisational adaptation
Fiol, 2002	Identity transformation model for firms undergoing strategic change	high-technology firm	participant observation over a 10-year period of identity transformation	longitudinal grounded-theory-building (based on Lewin's unfreeze, change, refreeze model)	Development of a model of identity transformation linking individual and organisational levels
Gioia & Thomas, 1996	Relevance of envisioned identity and image during strategic change	American academic institutions (colleges and universities)	25 interviews (university management and faculty), and 611 executives from 372 institutions surveyed	grounded-theory-building, external metaphor analysis	Under conditions of change, perception of identity and desired future image are crucial links between the firm's internal context and the members' issue interpretations
Gioia et al., 2000	Concept of organisational identity as a fluid, rather than stable construct	Body of Literature on Organisational Identity, ist ontology and literature on organisational image	Bodies of Literature	Literature Review and development of a process model of identity instability	Emergent model of adaptive instability of organisational identity. The need to create and maintain an enduring image of identity but simultaneously adapt to environmental change.
Gioia et al., 2010	The formation of a new organisational identity	Founding of an American College	33 semi-structured interviews (faculty), observation, internal archival data	grounded-theory-building	Internal, external, micro and macro influences as affecting factors during the formation of organisational identity. Social construction and social actor views of identity-related processes as mutually constitutive in the creation of identity

Table 4: Organisational identity literature review (Part 1 of 3)

Authors	Main Theme	Research Setting	Data Collection	Data Analysis	Main Results
Glynn, 2000	conflict over organisational identity within a cultural institution due to different professional backgrounds	Atlanta Symphony Orchestra	13 semi-structured interviews (managers and musicians), internal and external archival data	qualitative field study with interpretive analysis	Model of the construction of core capabilities as a function of identification and interpretive processes within an organisation
Glynn & Abzug, 2002	Effects of institutional isomorphism on corporate name change as a symbol of organisational identity	"Predicasts F&S Index of Coporate Change" and public audiences	2 simultaneous studies: -Study 1: 1,587 name changes of firms in a period of 5 years taken from public archival records -Study 2: several public audience groups surveyed with 41 to 612 respondents	Multi-part investigation with statistical regression analyses	Organisational name is isomorphic with culutural patterns, increasing the legitimacy of organisations
Golden-Biddle & Rao, 1997	Board directors' role conflicts and conflicts of commitment in a multiple (hybrid) identity organisation	American not-for-profit organisation	interviews, observation	Descriptive analysis	Influence of organisational and individual identities on a firm's board's role and the emergent concept of conflicts of commitment in a multiple identity organisation
Hambrick & Mason, 1984	"upper echelon perspective" on organisational behaviour and outcomes	N/A	literature, theory building	Synthesis of literature on managerial characteristics and resulting organisatioanl outcomes	Strategic choice and firm performance are partially predicted by managerial background characteristics
Haslam et al., 2003	approach to definition and delineation of organisational identity	N/A	literature, theory building	literature sythesis and theory building drawing heavily on psychology and sociology literatures	Identity is "more than a metaphor": It can be both an externally shared and and negotiated product and an internalised aspect of the collective self
He & Baruch, 2010	Interplay between organisational identity and legitimacy during change	2 British building societies	8 pilot interviews, 37 semi-structured interviews, archival data (in particular annual reports over 20 years)	grounded-theory-building	Effective role of narration and re-narration of organisational identity as a means to gain organisational legitimacy
Kjaergaard et al., 2011	effects of positive media coverage on the reconstruction of organizational identity within oganisational change	Danish hearing aid manufacturer	232 semi-structured interviews (all levels) over 10 years, internal and external archival data, direct observation	longitudinal field study, grounded-theory-building	positive media representations foster members' alignment around an emergent new understanding of organisational identity but may impede the development of the identity over time in order not to contradict previously positive media responses
Kogut & Zander, 1996	The effect of identity on learning and organisational processes	N/A	drawing on literature, linking identity and learning	theory development and literature review using prisoners dilemma thought experiment	Identity influences what is learnt in organisations, affecting e.g. Procedures, practices etc.
Livengood & Reger, 2010	The relationship between organisational identity and competitive dynamics	N/A	drawing on literature, linking identity with competitive dynamics	Development of a theory of Identity Domains and Competitive Dynamics	Organisational identity affects the firm's awareness, motivation and capability in engaging in new activities
Lowe et al., 2012	Organisational Identity and organisational capability development during internationalisation	Large international retailer (Tesco) during US-market entry	participatory research with observation and semi-structured interviews of 16 key participants, internal and external archival sources	grounded-theory-building with longitudinal dimension	Organisational identity and structural coherence in capabilities are necessary to achieve growth. Introduce 3 processes of capability development (transference, splicing, enhanced imitation). Actions to adapt or maintain organisational identity moderate the relationship between these 3.
Nag et al., 2007	organisational identity during strategic change	American high-tech telecommunications R&D organisation	34 in-depth interviews (with 8 senior and 12 middle management executives)	grounded-theory-building	the intersection of organizational identity, knowledge, and practice hindered the development of the new knowledge and undermined the broader strategic transformation effort

Table 5: Organisational identity literature review (Part 2 of 3)

Authors	Main Theme	Research Setting	Data Collection	Data Analysis	Main Results
Ravasi & Phillips, 2011	coherent identity management during strategic change	Danish audio-video systems manufacturer (Bang & Olufsen)	16 semi-structured interviews (with 10 senior & middle management executives), internal and external archival data	longitudinal case analysis with grounded-theory-building	identity management as a means to preserve congruence between organisational and individual identity of organisational members. Support for the concept of social validation of organisational identity dependent on actual firm behaviour, practices and structures
Ravasi & Schultz, 2006	Organisational reaction to identity threats	Danish audio-video systems manufacturer (Bang & Olufsen)	50 semi-structured interviews with 40 organisational members (some retired), identity seminars, archival data	longitudinal case analysis with grounded-theory-building	development of a theoretical framework for the interplay of construed images and organizational culture shapes and ist effect on institutional claims and shared understandings about the organisational identity
Reger et al., 1994	Acceptance of TQM as an example of organisational change	cases of TQM implementation	drawing on literature and specifically quotes by TQM specialists	Development of a dynamic model relating current and ideal identity, image, and ideal TQM	Implementation of change may be most successful if carried out incrementally, with individual changes large enough to overcome inertia but not too large to seem undesirable
Tripsas, 2009	Identity and organisational response to technology change	spin-off in the digital imaging industry	30 semi-structured interviews (senior & middle management), observation, internal and external archival data	longitudinal case analysis with grounded-theory-building, content analysis	Identity as a filter resulting in an interpretation of external conditions consistent with the organisation's identity, thus potentially hindering the exploration of identity-challenging technologies. Shifting identity to avoid missing such opportunities proves very difficult.
Voss et al., 2006	Divergence in organisational identity perception and firm performance	113 not-for-profit professional theatres	113 managing and marketing directors survey responses, interviews, organisational performance data	Descriptive statistical analysis	Negative effects of disagreement about organisational identity on organisational performance

Table 6: Organisational identity literature review (Part 3 of 3)

3.2.3 Identity and DUT2

As identity is essentially a cognitive concept, we suggest that it explains why firms will often refrain from activities which may be economically lucrative, but are incongruent with what is perceived to be central, distinctive and enduring to the firm's members.

Previous literature on strategic change has highlighted problems associated with obstacles firms can encounter when confronted with new imperatives, as members have been described as resistant to learning in order to preserve their pre-existing conceptions regarding their organisation (Brown & Starkey, 2000). In this context identity can be seen as the "cognitive, affective and psychological antecedent to competitive action and reaction" (Livengood & Reger, 2010, p.51).

On the cognitive level, the question of "who we are as a firm" may preclude the awareness and motivation regarding opportunities outside the firm's familiar market. Such opportunities may be simply incongruent with what is central, distinctive and enduring within the firm. In such cases, this

cognitive dimension will explain why firms may not engage in activities, which may be economically lucrative, and theoretically plausible (Nadkarni & Barr, 2008).

On the behavioural level, strong defence sector-specific identity is likely to lead to specialisation, manifested in routinisation and idiosyncratic structures and processes within the firm. This will arise from a drive for efficiency in the firm's familiar environmental context. Previous research has shown that the dismantling of routines is difficult, both due to cognitive constraints and due to the fact that such routines are often distributed throughout the firm and its functions (Leonard-Barton, 1992; Zahra et al., 2006).

Entry into non-defence markets will confront the firm with differing environmental conditions, and is likely to present to firm with challenges to its established beliefs, and many of these challenges will be unpredictable or subtle. This uncertainty, combined with cognitive rigidity regarding appropriate action in their more familiar markets will increase the likelihood that the firm will ignore, misinterpret or simply reject relevant feedback from the non-defence target market (Nadkarni et al., 2011). Further, they will not adapt their cognitive representations and routines sufficiently to the new market.

Additionally, a strong defence sector-specific identity is likely to lead to the firm favouring resource commitments to familiar markets and projects, making them less willing to engage in markets outside their familiar environment.

Due to isomorphic pressures within the defence industrial context, in particular the institutional forces emanating from the MOD, firms are likely to structure themselves to be aligned with the expectations of the MOD, as well as its own structures. Such structures may hamper the firm's ability to operate outside this environment.

These optimised routines and structures are likely to lead to structural inertia within firms with a strong defence identity. This will in turn affect the applicability of the firm's capabilities to the new context, and will likely affect the performance outcomes of any projects undertaken by the firm.

In summary, a defence sector-specific identity will be manifested at cognitive, behavioural and structural levels within a firm engaged in the defence industry. The strength of this identity will be correlated to the strategic focus of the firm on the industry, and its previous focus on such activities. These cognitive, behavioural and structural aspects will affect the likelihood of engagement in DUT2 projects by reducing their awareness of such opportunities, their motivation to pursue such activities and the applicability of their capabilities to achieve the goals of such projects.

Building on the above arguments, firms with strong defence sector-specific identities are will be less likely to identify and evaluate candidate technologies from non-defence sources, and their potential for application to solve defence sector problems. Such firms will in fact not be looking outside their traditional remit of defence, when searching for opportunities. The concept of the "wall of separation" therefore works both ways – the defence sector is idiosyncratic, and a firm with a strong sector-specific identity may feel it would in inappropriate to leverage non-defence technologies in defence contexts. Therefore this construct is likely to negatively affect the transfer of technology from non-defence to defence applications.

H1a: Strength of defence sector-specific identity will be negatively associated with a firm's likelihood of engaging in DUT2 projects from defence to non-defence

H1b: Strength of defence sector-specific identity will be negatively associated with a firm's likelihood of engaging in DUT2 projects from non-defence to defence

3.2.4 Technology Orientation & the Delivery of Technological Excellence

Technology orientation has been defined as "the use of sophisticated technologies in new product development, the rapidity of integration of new technologies, and proactively developing new technologies and creating new product ideas" (Gatignon & Xuereb, 1997, p.82).

This orientation is generally considered to be an internally focussed, "technology-push" approach, in comparison to a more market-oriented "customer- or demand-pull", and is based on the assumption that customers prefer technologically superior products and services (Wind & Mahajan, 1997). In essence, the firm focuses on product ideas and other courses of action, which emphasise state-of-the-art technologies, seeing innovation as a strategic and cultural priority (Hurley & Hult, 1998).

Firms with a strong technology orientation are likely to invest heavily in R&D, and be technically proficient, flexible and creative with regards to the technologies they employ. These technical skills enable the firm to entrench their position in existing markets, but also to exploit new market niches (Mu & Benedetto, 2011). Essentially, the firm is able to develop and commercialise innovative, better-designed products to the market (Wind & Mahajan, 1997), and use this technological superiority and distinctiveness to differentiate its products.

This focus on technological advantage, and rapid application of cutting-edge technologies, can form the basis of a competitive advantage, and in fact one that is not easy to imitate (Gatignon & Xuereb, 1997). This is driven by the role taken by defence agencies as early adopters of new technology, as

they essentially create markets for technological innovations, which may provide strategic advantages (Middleton et al., 2006).

In addition to driving this inimitability, defence agencies' role as early adopters can lead to the technological capability also being rare, particularly in the context of a civilian market. This rarity is caused by the idiosyncratic, defence sector-specific environmental conditions, which influenced the inception and evolution of the technological capabilities, which differ from the conditions in non-defence markets. Additionally, the development of these technological capabilities may have been funded by revenue streams, which were not available to potential non-defence competitors, such as direct R&D funding contracts, or revenues from procurement. This may enable defence suppliers to overcome the "cash-flow valley of death" which can otherwise inhibit the development process in commercial markets (Murphy & Edwards, 2003).

Evidence has shown that the technological foci in defence procurement have shifted radically since the end of the Cold War, and that they are moving considerably more in-line with technologies, which have greater potential for Dual-Use. For example, defence agencies frequently refer to C4ISTAR (or similar abbreviations) as a strategic priority, and it is unavoidable that these systems, or subsystems and components thereof, will find a range of non-defence applications. This can be contrasted to the heavy investment in procurement based on large-scale symmetrical warfare, which dominated Cold War strategy. Essentially, the potential for these capabilities to be valuable in non-defence contexts is likely to be enhanced.

In such a case, if a firm is appropriately organised, it may be possible and lucrative to leverage the technological capabilities of the firm into new non-defence markets. Therefore, we propose that a strong technology orientation will have a positive effect on the likelihood of DUT2.

H2: Technology orientation will be positively associated with the likelihood of the firm engaging in DUT2 projects from defence to non-defence

When considering the transfer of technology *into* the defence sector, we suggest expanding the technology orientation concept to a construct of the delivery of technological excellence. Due to the unique demands of defence agencies, and the high levels of specification and requirements for ruggedness and performance, many defence agencies build legitimacy by communicating their commitment to delivering technological excellence, going beyond leveraging the latest technologies and combining this with a dedication to highest quality, performance and reliability. In fact, several interview targets associate terms such as "pushing the envelope" with defence business. In order for technologies originating from non-defence applications to be applicable and legitimate in the

defence context, they must in fact provide superior solutions to what is available in the defence sector, as at least similar performance at a lower cost.

This focus on highest quality, performance and reliability levels is however likely to constrain the ability of a firm to transfer technology out of defence into non-defence markets. This is due to the fact that on average, the defence sector is willing to act as an early adopter of new technologies, pay a premium for this technological advantage. This is combined with the requirement for higher levels of performance and ruggedness in many projects which may not be needed in non-defence markets. It can be argued that price elasticity in the defence sector is lower than the average across the wider economy. This is supported by a statement by the defence secretary, Philip Hammond (Wright, 2012):

> *"That's the thing that I'm learning - that the application of the lean commercial model does have relevance in areas of the MOD, but, equally, you can't look at a warship and say, 'How can I bring a lean management model to this?' – because it's doing different things with different levels of resilience that are not generally required in the private sector."*

A firm's commitment to the delivery of technological excellence is therefore likely to increase the likelihood that they can leverage technologies originally developed for non-defence purposes in the defence sector, going beyond the commitment to sophisticated technology, and including a commitment to quality, performance, resilience and operational excellence.

H3: Technological excellence will be positively associated with the likelihood of the firm engaging in DUT2 projects from non-defence to defence

3.2.5 The moderating effect of defence identity on the relationship between technology orientation and DUT2

The above section describes the mechanisms whereby the strength of a firm's technology orientation will positively affect the likelihood of the firm's engagement in DUT2. A technology oriented firm operating within the defence industry is likely to develop technological capabilities, leveraging funding opportunities and procurement revenues which are essentially different to those operating in non-defence markets.

This can lead to the creation of a competitive advantage, based on the firm's development of such technological capabilities, and their repeated use over time. This may therefore form the basis for a firm to leverage this technological capability in non-defence markets.

However, we have previously shown that certain cognitive processes are present within firms, which consider themselves part of the defence industrial identity domain. These can lead to rigidities, which can inhibit a firm's ability to identify potential DUT2 projects, their willingness to pursue these projects DUT2 projects, and their success in initiated projects. Therefore, we suggest that this cognitive rigidity will moderate the effect of the firm's technology orientation on the likelihood of engagement in DUT2 projects.

If we assume that there is variation in the strength of firms' defence sector-specific identities, then it is likely that a stronger sector-specific identity will constitute a stronger inhibiting factor on the exploitation of a given technological capability in a given non-defence market (i.e. on which falls outside the perceived identity domain).

H4a: Strength of defence sector-specific identity moderates the effect of technology orientation on the likelihood of the firm engaging in DUT2 projects from defence to non-defence, in that high identity strength will weaken the positive effect of technology orientation

H4b: Strength of defence sector-specific identity moderates the effect of technological excellence on the likelihood of the firm engaging in DUT2 projects from non-defence to defence, in that high identity strength will weaken the positive effect of technological excellence

3.2.6 Human asset specificity

This dimension refers to the technical and professional skills and knowledge underpinning the activities of the firm. This dimension is often regarded as the key to core capabilities (Teece et al., 1990) and this factor is likely to be particularly strong in technology-intensive defence procurement. Small changes from a technological standpoint may challenge the existing identity prevalent among organisational members, if by pursuing this path, the organisation violates the beliefs regarding the central, distinctive and enduring features associated with its existing identity (Tripsas, 2009).

Participating in the defence sector is likely to require a high level of adaptation to the particular setting. This includes the specialisation of knowledge to the context. Nonaka (1994) illustrates that social processes underpin the creation of specialised knowledge, and that these processes encourage the validation, refinement and enrichment of knowledge within a given context of action.

In this context, we describe human asset specificity as the organisation's ability to access and deploy this specific body of knowledge and skills outside the organisation's existing (defence) context (Zaheer & Venkatraman, 1995; Nonaka, 1994; Teece, 1998). In essence, the construct describes the degree to which critical areas of knowledge of a defence firm are specific to the requirements of the defence industry as a whole (Subramani & Venkatraman, 2003). Prior research has shown that

specialised knowledge is often domain specific, and imperfectly transferable to other contexts (Shanteau, 1992). Human asset specificity has also been described as assets arising from "learning by doing" (Williamson, 1996).

The nuances of a particular domain, and the organisation's members' adaptation to these, will affect the problem solving behaviour as well as cognitive approach to identification and pursuit of opportunities by the organisation as a whole, as the members' skills are deployed in a context with a specific, often idiosyncratic set of rules and expectations.

Von Hippel (1994) also demonstrates that knowledge generated in specific contexts is subject to social factors which lead to the knowledge itself becoming inherently "sticky", i.e. "manifested in context-specific judgements in which some events are deemed meaningful and worth attending to while others are considered irrelevant and ignorable" (Subramani & Venkatraman, 2003, p.50). This is particularly likely in situations where the knowledge, as well as the ability to coordinate this knowledge, is distributed among many actors within the firm, and underlies a complex technological capability.

Previous literature on inter-firm relationships has shown that patterns of specialised expertise are often embedded in the context of their industries, and the particular requirements of firms / buyers further upstream (Uzzi, 1997). We suggest that this effect will be particularly strong in an environment with strong institutional pressures such as defence.

Therefore, we expect a stronger degree of skills & knowledge specialisation to be negatively associated with the likelihood that a firm will engage in DUT2, and the success of any initiated projects.

In essence, if the firm's skills and knowledge are highly optimised for one context, this may have several negative effects on the ability of the firm to deploy these knowledge resources in other contexts. Firstly, a high focus on optimisation of the depth of knowledge in a particular area, rather than the breadth of knowledge in ancillary fields, will constrain the firm's strategic options to this particular area, although it may allow them to gain dominance in the specific field. Essentially, weaknesses may exist in non-dominant fields. Further, such dominance in a particular field may also inhibit the firm's ability to attract new employees (and their knowledge and skills) from other fields, as they may not associate the firm with their chosen field. Particularly if the field is defined and perceived to be heavily aligned with the defence industry, this may constrain the abilities and willingness of employees to recognise and pursue related projects which may in fact be technically similar, but do not fit the employee's concept of his/her skills and knowledge set.

The term field may refer to technical fields, but also to other professional fields. This may have effects on the power relations between, for instance, marketing managers and technical specialists within a firm. The implication of this is that the firm may be lacking in skills in areas necessary to identify and take advantage of new, non-traditional opportunities. This is a result of the three-fold effect of low importance placed on employment and compensation of such employees, as well as their relative lack of power in determining strategic direction and decision-making on e.g. new product development projects, as well as the lack of prestige associated with such functions. In fact, employees who take on marketing roles may be tightly aligned with the defence sector. In several interviews, industry experts and participants mentioned that many MOD-facing personnel themselves ex servicemen and -women are "selling to their old friends".

In essence, in the defence context, this will lead to the skills and knowledge embedded within a heavily defence-focused firm being based upon a combination of technical competencies and selling specifically to the MOD and other defence agencies. This specificity of this skill and knowledge set may present a hindrance, if the firm were to seek and attempt to engage in non-defence markets.

In conclusion, the above factors can be distilled into the following two aspects of skills and knowledge specificity, which will be negatively associated with DUT2.

Firstly, the knowledge embedded in employees is likely to have been socially constructed within the defence domain context. The stronger this effect, the more likely it is that the particular nuances of the understanding, coordination and deployment of this knowledge will be defence specific and therefore inapplicable in non-defence markets. This will often be manifested in particular behaviours and routines which have evolved over time through codification and institutionalisation of repeatedly successful actions, as well as the cognitive understanding as to wherein the individuals' skills and knowledge lie.

Secondly, the strategic-level investment in areas of skills and knowledge, which are particularly relevant to defence, is likely to be stronger in firms with a strong defence identity. Therefore, this is likely to lead to lower general applicability of the fields and technologies to which these skills and knowledge belong outside of the defence context. This in itself will lead to a reduction in the number of related opportunities for DUT2. As competitive advantage is to a large extent based on employees' specialised skills and knowledge, and these skills and knowledge are socially constructed, a high status might be associated with working for such a defence-focussed organisation, which in turn will attract more individuals with such skills, knowledge and experience, which may then reinforce this effect over time.

H5: Human asset specificity, as embodied in the optimisation to the defence sector of employee knowledge and skills, will be negatively associated with the likelihood of the firm engaging in DUT2 projects

3.2.7 Business function specificity (Procedural asset specificity)

Nelson & Winter (1982) illustrate that over time, specialised routines and standard operating procedures evolve, through the codification and institutionalisation of successful patterns of behaviour and execution of activities. Here, we suggest that such routines are embedded in the core business functions of the focal firm, and that these functions are adapted by the organisation to meet the requirements and expectations embodied in the institutional forces within the defence industrial identity domain.

The resource-based perspective (Penrose, 1959; Teece, 1982) proposes that firms acquire the necessary resources to compete within a certain environment, and exploit these resources to generate revenues. Barney (1991, p. 101) defines resources as "all assets, capabilities, organisational processes, firm attributes, information, firm knowledge, etc., controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness." As these resources can include organisational routines (Nelson & Winter, 1982), or in fact managerial capacity (Hambrick, 1987), and can be highly specific, difficult to imitate, and difficult to substitute (Dierickx & Cool, 1989), the question of fungibility becomes complex. Taking a bounded rationality approach, Cyert & March (1963) argued that managers may be constrained in the application of potentially fungible assets in domains, which are not closely related to their original use. Further, informational constraints on this usage may exist (Anand & Singh, 1997). Taking an evolutionary approach, it can be said that industry- and business-specific factors positively influence the specificity of routines and resources (Levinthal, 1991). Furthermore, these resources and routines are embedded in specific business functions within the organisation. Therefore, highly adapted business functions in the defence sector may constitute a barrier to DUT2.

Business functions consist of systems of workflows and routines, which are customised to meet the requirements of the organisation's customers and other stakeholders. As such, it is difficult to alter such routines once established. This concept of procedural asset specificity (Malone et al., 1987; Zaheer & Venkatraman, 1994) can constitute a lock-in effect, as it can make it costly for the organisation to escape its immediate institutional environment, should these adaptations be inappropriate in other contexts.

High-technology firms in particular are likely to invest heavily in technical systems and skilled employees, and may therefore be subject to a degree of technological lock-in. It is also realistic to assume that these systems may be tailored to meet the requirements of particular customers. This is likely to be particularly relevant in the defence context, where the customer has very specific requirements and is often in the market for technologically sophisticated, customised equipment, and is willing to pay a premium for products, which meet their requirements and bestow them with a technological advantage. This phenomenon has been noted in a defence-specific context by Stowsky (2004), stating that often military R&D projects result in products which, when leveraged for dual use, are inferior in price and quality to comparable products originating from commercial firms. If the environment in which defence contractors operate influences the development of specific and therefore distinct routines, procedural assets and business functions, this may influence the opportunities for technology transfer. As the opportunities for learning and innovation can be constrained by the organisations previous experience and technology base (Teece, Pisano & Shuen, 1997), it can be assumed that the fungibility of such procedural assets can be a function of organisational conditions (Anand & Singh, 1997).

In order to conform with the expectations associated with the defence identity domain, and the specific rules and regulations of customers and other stakeholders within the defence industry, a focal firm is likely to adapt its specific functions within the product development process, such as R&D, design, manufacturing and after-sales support. We propose that these processes are underpinned by a firm's ability to codify, structure and deploy the knowledge of its employees to perform such functions.

Our Case Studies have shown that, for instance, defence focussed firms may be more inclined to value functionality significantly higher than "aesthetics" – i.e. a military customer does not have the same demand for industrial design as a civilian customer, in particular a consumer, will have. Military customers will place significant value on ruggedness and reliability, particularly in the context of demanding environments, such as the significant environmental challenges regarding current operations in Afghanistan and the Persian Gulf.

Defence agencies are also likely to set additional, detailed specifications in their tendering process, further inducing firms to adapt significantly to their needs (Cronberg, 1994). In this context, firms may have to greatly adapt their technical systems in order to meet this demand. In fact, "over-specification" is an often-mentioned barrier to successful involvement in defence projects. Significant investment and optimisation of capabilities in order to foresee and meet these specifications is likely

to be a disadvantage compared to civilian-oriented firms who will have a stronger focus on being lean and cost effective, and launching larger runs of more homogeneous products.

Another characteristic of defence markets is that production runs are generally relatively small, compared to many civilian markets (Hartley, 2011). This will lead to a smaller number of units over which capital investment, R&D costs and other functions can be spread. Case studies of firms with a relatively low defence focus have shown that firms usually expect higher margins (albeit perhaps lower volumes) from defence projects.

Another important point is that many defence projects, in particular larger, more technologically sophisticated ones, have very long life cycles, potentially running into decades (Bennett, 2010). The development process alone can be significantly longer than in comparable civilian high-technology sectors. As time to market is a major source of competitive advantage in fast moving civilian technology markets, this adaptation to the long, highly specified, controlled and monitored defence procurement process must present a potential barrier to DUT2.

These aspects lead to the perception that defence firms are generally less lean than comparable civilian firms. Although there will be macro-level effects driving this, manifested in the procurement process, we propose firm-level effects will also drive the lack of leanness.

This optimisation is likely to have an effect on the applicability of these systems in the context of entering new markets. For instance, if we assume that defence customers are likely to purchase low-volume, highly customised and technologically sophisticated products at a relatively high price (and margin to the firm), it may be challenging for a firm to adapt its processes, procedures and systems to access commercial markets which may not be willing to pay such a high price, and would be more willing to accept a lower level of technological sophistication and customisation. In such a case, a technologically sophisticated firm highly adapted to defence markets may be at a Competitive Disadvantage as it may not be able to engage in high-volume, low margin (mass)-markets.

H6: Business function specificity (procedural asset specificity), manifested in highly optimised defence sector-specific core functions, will be negatively associated with the likelihood of the firm engaging in DUT2 projects

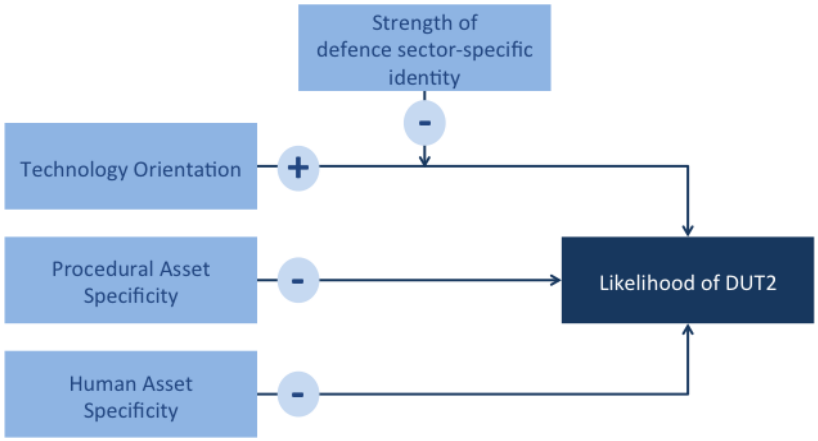

Figure 13: Model of the likelihood of DUT2

3.2.8 The value placed on secrecy and confidentiality

Additionally, another aspect which is often associated with DUT2 is the firm's attitude to secrecy. This attitude is embedded in managerial systems related to the control of knowledge within the firm, and in relation to other stakeholders. In this particular context, where technological advantage is paramount within the military environment, and secrecy is highly regarded within high-technology projects, a high propensity to attach a value to secrecy will have an effect on DUT2. This effect goes beyond the regulative aspect of security classification in the defence industry, and extends to cognitive affects associated with the values and norms dimension of capabilities, and hence also rigidities (Leonard-Barton, 1992).

It must however be noted that a strong sense of the value of secrecy or confidentiality is not solely a characteristic of defence markets. Many firms whose competitive advantage is based on advanced technology will be faced with challenges relating to knowledge regarded as commercially sensitive. The following quote from a senior figure in a defence supplier illustrates this point:

> *"The technology we deal in rarely has any military sensitivity but does have a lot of commercial sensitivity."*

There are, however, additional challenges relating to military secrecy, as even the involvement of an organisation in certain projects may be coercively regulated by government. This leads to significant measurement issues, which will be discussed in a subsequent section.

Although a strong and rigorous attitude to secrecy and control of information is likely to strengthen the legitimacy of a defence firm in the eyes of defence agencies and other actors in the wider defence industrial institutional environment, it may hinder their ability to achieve success in commercial markets.

Literature exists, which links the strength of an industry's appropriability regime and the preference of secrecy over IPR to the nature of relationships in the context of inter-firm technology transfer (Hagedoorn et al., 2008). This article cites several previous studies which had found there to be a large number of industries which prefer to use secrecy to protect their technologies (Cohen et al., 2000; Arundel, 2001). As in firms with otherwise weak appropriability regimes, firms in industries with significantly secretive environments tend to favour closer collaboration through partnerships and embedded agreements over standard, arms length, market based transactions. These broader agreements offer the transferor a higher degree of monitoring and control (Anand & Khanna, 2000), which may be due to regulative forces, but also subsequent cognitive structures inherent in the industry.

A strict adherence to secrecy will likely be negatively associated with successes in collaborative work. Although there is a need to protect proprietary information in many cases, many potential partners may not be willing or able to engage with a firm which is systematically and culturally not willing to – or capable of – engaging in collaborative, knowledge-sharing activities. Building such relationships requires the gradual development of trust, which takes time. As market knowledge and other specific capabilities may be weak in the transferor firm, a lack of willingness to openly share technology may lead to lost opportunities. Again, this may have legitimate regulatory reasons, but may be due to industry specific cognitive effects.

Additionally, a strong focus on technological leadership, and this leadership being the foundation of a firm's competitive advantage, may incentivise the firm to remain within the highly controlled defence markets where this strong regard for secrecy acts as an additional barrier to entry in the firm's strong market segments. This may be reinforced by the long development cycles involved in defence work. Commercial, civilian-oriented high-technology firms are likely to be incentivised to develop products quickly, and get them to market swiftly, already predicting the product's replacement. Although this will be the case in the defence industry, the process is likely to be slower, thereby increasing the importance of contemporary technological developments, and hindering their ability to compete in faster-moving civilian markets.

H7: A strong value placed on secrecy will be negatively associated with the likelihood of the firm engaging in DUT2.

Unfortunately, this hypothesis was not tested in the quantitative analysis due to significant measurement issues. Briefly, responses to questions regarding level of secrecy seemed positively associated with the actual sensitivity of the target firm's activities, however, several non-responses and minimum responses were received from firms which are likely to be involved in sensitive work.

These responses, combined with discussions with industry practitioners in the survey development phase, led to the measure being dropped from the quantitative analysis. This omission is further detailed in the questionnaire design segment in the methods section.

3.3 The effect of reliance on defence revenues on strategic reorientation to non-defence activities

This section will first outline the contextual background relating to pressures for defence suppliers to diversify to non-defence activities. Due to recently announced defence spending cuts, these pressures are likely to intensify. The section will differentiate between the diversification options open to defence firms and the effects the government narratives regarding the cuts will have on firms, and the firm-level effects which may lead to different strategic responses. Subsequently, a theoretical approach to these effects will be outlined and hypotheses developed.

The UK domestic defence market is currently characterised by cost pressures on procurement and a downsizing of the military in general. This of course poses a threat to defence firms who rely on MOD spending.

Critically, cuts to defence spending are affected by the long lead times, contractual arrangements and complexity of the relationship between MOD and the DIB. In essence, defence cuts will lead to a lack of new business, however, firms involved in existing, especially large, complex projects, will likely retain these revenues. Therefore, on balance, at least in the short- to medium term, these defence cuts in the UK are likely to preclude the opportunity for business growth, as opposed to leading to a loss of existing business.

As a case in point, several current large development and procurement projects (e.g. JSF, Astute, CVX) are likely to proceed, albeit perhaps in a smaller number. Particularly the JSF programme adds an additional level of complexity, namely the international dimension.

As the cost and complexity of defence systems has risen, coupled with cost pressures on defence which have existed for decades (albeit not so severe), most nations cannot afford a complete "cradle-to-grave" capacity across a range of defence capabilities. This leads to international collaboration on development and procurement projects, or to trade of existing systems (or arrangements which fall between these two points on a continuum). The JSF project is an excellent example of these forces and mechanisms in action.

It can be argued that the US possesses the only defence industry with the breadth and depth (and funding) to cover the "cradle-to-grave" capacity across a wide range of capabilities. However, even in the US context, the JSF project has involved collaboration with international partners, notably BAE Systems and Rolls Royce. As the manufacturing stage of the project is currently in its early stages, and planned to continue until 2016, substantial involvement in this project will provide considerable, relatively certain revenues for the future (Gertler, 2012). In addition, additional services such as spare parts, maintenance etc. will only add to this.

As mentioned before, large UK defence firms have become increasingly global. These firms have long recognised the advantages of hedging their geographical dependencies, and become large, global entities with access to multiple markets. This is a key factor in the effect of defence spending on firm's strategic orientation regarding which markets they intend to operate in.

Furthermore, although the above relates primarily to prime contractors with the structural and financial resources to grow globally, these implications can be expanded to include smaller firms who make up constituent parts of the supply chains for complex defence systems. Although a prime contractor takes the role of supply chain manager in large defence projects, they still draw upon a range of suppliers within the UK. These suppliers will not have the direct access to these foreign markets, but are still likely to experience a spill-over effect of the prime contractor's activities in other markets.

Therefore, due to many factors, which have been affecting the UK defence industry for many years, the UK defence industry has become a large, globally oriented industry. In fact, UK defence exports rank sixth behind the US leading the statistics (Stockholm International Peace Research Institute, 2012) (Figure 14).

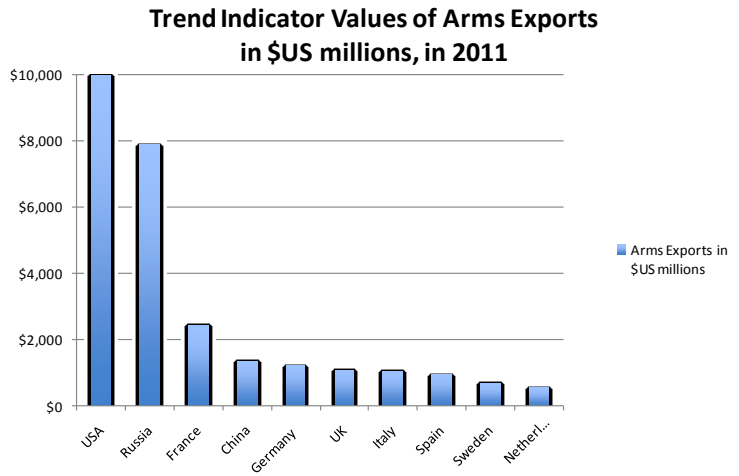

Figure 14: Arms exports US$ in millions (Stockholm International Peace Research Institute, 2012)

In this context, the question arises: How does a strong reliance on defence revenues affect a firm's planning for future strategic orientation? Specifically, how does it affect the firm's intentions regarding the strength of their orientation to non-defence markets?

The global nature of the defence industry can be seen as a hedging mechanism against defence cuts in a particular country or region. In spite of this it can be argued that in many circles, defence firms are seen to be heavily affected by defence cuts, making the business less attractive overall. There are essentially two camps regarding this issue.

On the one side, it is argued that budgetary pressures in the domestic markets of the major defence suppliers (US and UK) will be detrimental to these firms, particularly to those with a strong reliance on defence business, with little non-defence business to compensate for these reductions. Also, the winding down of operations in Iraq and Afghanistan contribute to a bleak outlook for defence in general. Reductions in defence budgets and the number of armed forces personnel would seem to lend credence to this view.

However, this opinion is countered by several influential factors. Firstly, as discussed above, the major global defence contractors have been repositioning themselves substantially to gain global presence and market access. Although the size of their main, traditional markets may be declining, the economies of many countries in Asia, and South America (most notably Brazil) are growing significantly, and defence markets in these countries grow accordingly (ReutersVideo, 2011). Many UK based defence firms (or firms such as Thales or Lockheed Martin with a strong UK presence) are well positioned to benefit from this growth, as Thales' CEO pointed out in the interview mentioned before (ReutersVideo, 2011).

Secondly, the changes in defence agencies demands must be considered. Since the end of the Cold War, there have been great changes in the technologies employed in the armed forces. Technologies relating to C4ISTAR, Unmanned Aerial Systems, and other electronics-intensive technologies and systems have displaced the "traditional" defence procurement of Cold War era equipment, as these new technologies have been developed with the modern threat environment in mind. These changes in technologies, military strategy and tactics, and indeed the scope of defence and in particular its relationship to "security", have redefined the landscape of the defence industry. In fact, it can be argued it is much more difficult to differentiate it from other industries, as many of these technologies are inherently dual-use.

Many of these particular technological fields are characterised by the fact that technological leadership is often driven by non-defence sales and technological breakthroughs. Therefore, it can be

argued that the non-defence sector has been driving many advances in areas such as semiconductors. Additionally, the cost pressures to which these firms are often exposed to have driven them to evolve leaner, more cost effective structures, albeit often associated with high throughput.

This feeds back into the decline in defence spending, increase in transparency and move toward more competitive procurement. I.e. defence agencies seem more likely to engage with non-traditional suppliers, if they can offer high technology at a lower price than a dedicated defence supplier who may have been exposed to the traditional defence environment and not achieved the same level of efficiency, which is driven by mass production, standardisation and price sensitive consumers.

These forces have been recognized by many defence suppliers. Although many of the largest firms continue to base their competitive advantage around their strong ties to defence agencies and government, and therefore are strongly reliant on defence revenues (e.g. BAE, Lockheed Martin), many have been increasingly moving into non-traditional, but technologically related markets, such as non-defence satellite technology, telecoms, aerospace, etc. One example of such a move is the recent acquisition of Thrane & Thrane by Cobham, which has increased the share of Cobham's revenues from non-defence from roughly one quarter to nearly a third (Financial Times, 08.08.2012). Cobham's CEO underlines this strategy in an interview, stating that:

> *"[Cobham has] an overall strategy that [they are] happy with [… and that they] like defence, but [their] future acquisitions will be designed to tilt the balance of the business towards commercial aerospace programmes. [They] do a lot with Airbus; [they would] like to do more with Boeing. Managing that shift means making strategic acquisitions..." (Shotter et al., 2012).*

Therefore, defence suppliers who have recognised these trends, and have structured themselves accordingly, are likely to be shielded from the effects of defence cuts. Firstly due to their geographical spread, and secondly due to the fact that they have been at the forefront of the development of technologies, which may potentially have non-defence applications.

The resource-based view indicates that firms acquire the necessary resources to compete in a given context, and leverage these in product markets to generate revenues (Penrose, 1959; Teece, 1982). Further, competitive advantage can be gained by the acquisition and maintenance of resources which are highly specific, difficult to imitate and difficult to substitute (Dierickx & Cool, 1989). These resources are often embedded in routines (Nelson & Winter, 1982), or in fact in managerial capacity (Hambrick, 1987). Due to path dependency in the development of such resources, they may acquire

"stickiness" (Barney, 1991). This can be contrasted with the fungibility necessary to apply these resources in other contexts. The stickiness can be compounded by managers' inability or unwillingness to find uses for otherwise fungible assets. However, this may be counteracted if performance levels in certain domains fall below certain "aspiration levels" held by managers (Cyert & March, 1963). Effectively, industry decline may act as an impetus for managers to seek diversification opportunities they otherwise may not had sufficiently valued, or had associated perceived uncertainty and risk.

The effect of overall defence revenue on strategic reorientation to non-defence activities

In line with the above arguments, the question arises: Will high reliance on defence revenues affect the firm's future plans regarding non-defence activities? Specifically at this point in time, pressures on the defence industry are often reported in the media, due to austerity measures and the winding down of operations in Iraq and Afghanistan. In this climate, heavy reliance on defence revenues may be seen as a weakness going forward. Therefore, it can be argued that reorientation toward non-defence revenues may be positively influenced by defence revenues as a percentage of overall revenue.

However, this effect cannot be taken in isolation. As outlined above, many defence firms have been hedging their bets with regards to traditional sources of revenue. The two methods of doing this have been identified as: 1) geographic diversification, and 2) commercialisation of technologies outside the traditional defence sector (see matrix based on Ansoff, 1957 - Figure 9).

Therefore, this relationship is likely to be influenced by many factors, which may not be clearly separable. At the high end of defence specialisation, one finds heavily entrenched, specialist defence suppliers whose competitive advantage is heavily based on their relationships and position within defence industries. There are also many smaller firms whose technological capabilities lie in fields for which there is little non-defence interest. However, there are also a significant number of technology-based firms of all sizes, who are already strategically oriented to leverage their technologies in defence as well as non-defence markets.

Therefore, the measure of overall defence revenue as a percentage of total revenue is problematic and likely diluted, as total defence revenues can come from many sources, such as exports or selling to downstream defence contractors. However, in the case of the UK, the measure of MOD spending is more likely to have an effect on an organisation's intent to move toward a higher degree of non-

defence activities in the future, as it is a clearer measure of exposure to revenue sources which are commonly believed to shrink in the short- to medium term.

The effect of MOD revenue on strategic reorientation to non-defence activities

The UK MOD has announced that it will cut defence spending in the coming years. Due to the forces described above, this is likely to have a lagged effect on actual defence spending, as many projects have very long life cycles, however, the government and MOD are communicating quite clearly that they wish to cut spending. This will have a signalling effect on a tangible as well as cognitive/psychological effect to firms operating in the market.

Whereas the overall percentage revenue from defence figure constitutes a figure, which is potentially geographically heavily dispersed, this figure is a clear indication of a firm's reliance on the UK MOD. Therefore, the relationship between this figure and intent to strategically reorient toward non-defence activities is likely to be positive and significant, on average.

H8: A higher percentage of revenues from UK MOD will be associated with a stronger intent to reorient to non-defence revenues

The effect of defence sector identity on strategic reorientation to non-defence activities

We have outlined in sections 3.2.1 - 3.2.3 our theoretical framework regarding the effect of defence sector-specific identity on DUT2. In this case we use the same construct to predict a firm's intent to grow its activities in non-defence markets.

Given the current climate in the UK defence sector, it is likely that the "aspiration levels" (Cyert & March, 1963) of defence business are weakening, as it would seem opportunities to grow in this domain are reducing. However, a strong identity in the sector, which is often built upon path-dependency and strong experiences of success in the industry, are likely to diminish this effect. Therefore we expect a strong defence sector-specific identity to have a negative effect on the intent to strategically reorient into non-defence activities.

H9: A strong defence sector-specific identity will be negatively associated with the intent to reorient to non-defence revenues

Technological Excellence and strategic reorientation to non-defence activities

We do however expect technological excellence to be positively related to the intent to grow non-defence activities. This is due to the fact that firms with a strong commitment to excellence and with a proven track record of delivering high technology are likely to perceive potential value-creation activities due to potential competitive advantage in non-defence markets, where they may offer technologies which may be superior to those of potential competitors. Again, as we are considering intentions for future behaviour, this relationship is based on the perceptions of top managers as to how they may effectively grow their businesses. Also, the responses were given at a time where many defence contractors are being forced to re-evaluate their business strategy going forward, and non-defence markets may present a higher potential for growth than the defence sector.

H10: Technological excellence will be positively associated with the intent to reorient to non-defence revenues

The interaction of defence sector-specific identity and technological excellence

Based upon the reasoning set out in section 3.2.5, we argue that defence sector-specific identity will moderate the positive relationship between technological excellence and the intent to strategically reorient away from defence, in that a stronger identity will weaken the effect. As outlined above, this is due to the fact that a strong sector-specific identity is likely to be associated with sector-specific managerial mental models and cognitive schemas, which will limit the ability and willingness for managers to engage in activities which are perceived to be incompatible with this embedded identity.

H11: *Strength of defence sector-specific identity moderates the effect of technological excellence on the intent to strategically reorient to non-defence activities, in that high identity strength will weaken the positive effect of technological excellence*

These hypotheses will be tested using data collected using a survey of the database of the Aerospace, Defence and Space trade association A|D|S. The following section outlines the steps taken to construct this survey, providing detail on the methodological aspects of the project. The methodological approach is based primarily on a combination of exploratory qualitative work and empirical quantitative analysis (Kim & Miner, 2007). By adopting this approach, we take into account that the DUT2 phenomenon is complex, and embedded in a unique and intricate context, i.e. the defence industry. Therefore I use the exploratory field work to build a strong link between the theory and statistical analysis, ensuring a high degree of validity by iteratively consulting with industry

experts and other sources to capture the complexity inherent to the phenomenon throughout the phases of the project.

4 Methodology

The overarching goal of this project was to investigate the phenomenon of DUT2, namely to identify cases in which technology has transferred from defence to non-defence applications, and cases where this has not occurred. Subsequently, patterns were to be identified which are correlated with successful DUT2 outcomes. These patterns were then to be formalised and ultimately, a contemporary overview of the phenomenon, and factors contributing to it was to be created. The PhD studentship was set up to this end with EPSRC funding.

Early in the process it became clear that operationalising this research context was challenging. The area of DUT2 is multifaceted, and involves a range of business functions, institutional stakeholders and environmental forces. In fact, the defence industrial environment itself is complex and challenging in its own right.

This study combines exploratory fieldwork with quantitative hypothesis testing in order to establish a strong link between our theories and our statistical methods. This approach is based on the methodology of Kim & Miner (2007).

Therefore, significant time and effort had to be spent in an exploratory phase in order to take stock of previous attempts to address the phenomenon, and to leverage and synthesise expert opinions as to precisely what is actually happening in the case of DUT2. Additionally, understanding the phenomenon requires a rich understanding of the idiosyncratic defence industrial context. This is again complicated by the fact that the defence industry has undergone many changes since the end of the Cold War, and since the rise of asymmetric warfare[7] and threats posed by opponents other than sovereign nation-states.

Therefore, one contribution of this study is an up-to-date overview of the forces affecting defence suppliers in the UK. This overview was created in the form of the previous sections dealing with the defence industrial environment. Only after generating this overview could a more rigorous, explanatory research methodology be developed.

During the exploratory phase, it clearly emerged that a focus on defence to non-defence technology transfer would only capture a part of the relationship between technologies in the defence sector, and in the wider economy. Therefore, technology transfer in the other direction has been included in

[7] Asymmetric warfare can be defined as warfare between opponents whose relative military strength and/or strategy or tactics differ significantly – in this case the shift from the Cold War doctrine of opposing the USSR and its allies to the current situations in Iraq and Afghanistan.

the study. By taking this bi-directional view, a richer overview of the phenomenon can be created. In fact, a significant number of respondents claim that this non-defence to defence technology transfer occurs at a greater magnitude, and its magnitude is increasing.

The following section outlines the research process, starting with the exploratory phases taking stock of existing knowledge, and synthesising knowledge from a range of experts at different points in the system. Subsequently, using theoretical lenses from the management literature, a theoretical construct was created which will enable extrapolation of the study's findings to other industries, which have similar characteristics to defence. Only then could testable hypotheses be generated and a survey instrument be designed. Only rarely have researchers attempted to survey a population of defence firms to this end, and existing studies must be updated to take into account the contemporary defence environment.

Subsequent to the research process section, the elements of the survey study methodology will be described in greater detail and justified. Then, the next section will describe the survey questionnaire and its variants.

Despite the challenges in obtaining responses in this context, a novel dataset has been constructed and used for quantitative analysis, in order to identify firm-level factors influencing DUT2.

This section will continue with an overview of the research process, divided into steps covering the convergence of methods from the exploratory phases, to survey design and implementation and finally data analysis and discussion. Subsequently, the section provides more detail on questionnaire development, including scale development and treatment of reliability and validity.

Firstly, Table 7 presents an anonymised list of interview participants contacted during this study.

Position	Company Description
Procurement Officer	Government
Scientist	Government
(former) Defence Science Strategy Director (CTO)	Industry
Engineer	Industry
Engineer	Industry
Engineer	Industry
Managing Director (SME)	Industry
Defence & Security Consultant	Industry
Technology Consultant	Industry
Director of Strategic Consulting	Industry
Principal Technology Consultant	Industry
Chief Technology Officer	Industry
Technical Director	Industry
Former Technical Director	Industry
Managing Director (SME)	Industry
Director of Sales & Marketing	Industry
Director, Business Strategy	Industry
Managing Director (SME)	Industry
Commercial Director	Trade Association
Technology Advisor	Trade Association
Deputy CEO and Divisional Managing Director	Trade Association
Managing Director	Trade Association
Divisional Director	Trade Association
Professor (Emeritus)	University
Senior Lecturer	University
Institute Programme Manager	University
Business Development Manager	University
Senior Lecturer	University

Table 7: Anonymised list of interview participants

4.1 Research process

This section gives a general overview of the process carried out in this research project. Figure 15 provides an overview of the process of which each step is briefly outlined below. Although the process is described as being linear, in practice it was iterative in nature. During the project, experts were interviewed and later re-visited to add depth and detail to the theoretical model and to ensure validity regarding empirical design choices. This is based on the methodology of combining exploratory qualitative work with quantitative hypothesis testing to ensure the effective treatment of this complex phenomenon (Kim & Miner, 2007).

Figure 15: Overview of the research process (based on Kim & Miner, 2007)

1) *DUT2 Literature review phase*: The literature regarding the DUT2 phenomenon is sparse and fragmented. An in-depth review of literature pertaining directly to DUT2 was undertaken, and complimented with other literatures. These included research regarding defence firms, their idiosyncrasies and interactions with the wider economy, and literature regarding related forms of technology transfer, e.g. public to private sector technology transfer. One particularly important point is that a large amount of the DUT2 literature was written several years or decades ago, giving rise to the opportunity to update knowledge in the field taking into account to modern defence institutional environment (post Cold-War, post 9/11)

Goals: To assess existing work and findings in the field; to avoid duplication of work; to review previous research questions and methodologies within the DUT2 context; to assess the contemporary value of existing studies and identify areas in need of updating; to create a fundamental framework of known or proposed factors which may influence DUT2

2) *Exploratory phase*: A considerable amount of time in the early stages of the study was taken to gather preliminary information, opinions and other input regarding which firm-level characteristics impact the likelihood and success of DUT2 projects. This phase included semi-structured interviews, visits to firms and an industry association, attendance at MOD and other stakeholders' conferences, seminars and other events, as well as telephone interviews and informal discussions with industry experts. In addition, many other sources were used such as government White Papers, internal MOD procedural and particularly procurement guidelines (where available), websites and documentation created by MOD and related organisations aimed at engaging suppliers. Furthermore, interviews throughout the questionnaire design phase were used to ensure validity regarding empirical design choices.

   Goals: To add depth to the characterisations of the defence institutional environment, and the isomorphic responses of firms within this environment; to identify and characterise firm-level structures, procedures and cognitive frameworks which may affect DUT2; to refine the research questions and to approach a formal operationalisation of these constructs.

3) *Management Research literature review phase*: Once an overarching overview of the industry and its important stakeholders had been created, it was necessary to identify and leverage appropriate management literature in order to create an ordered, formalised and theoretically anchored systematic overview of the phenomenon and influential factors. Several streams of literature were considered, however the Capabilities literature lends itself well to this phenomenon, complimented with the body of institutional literature, and a particular emphasis on the organisational identity literature. Synthesising these three streams enables a firmly anchored conceptional framework to describe and analyse DUT2, but also to capture the particular idiosyncrasies of the defence industrial environment.

   Goals: To further refine the study's research questions and constructs; to select appropriate theoretical lenses and theoretical background to underlie and support the development of a theory of DUT2

4) *Theory formulation*: Equipped with in-depth knowledge of the field, and appropriate "lenses" and tools to view the phenomenon from a management perspective, theory was formulated to conceptualise and relate various constructs in a formalised manner. The overarching goal was to formulate theory which can both a) capture the industry-specific forces at work in the context of DUT2, and b) be generalisable to other comparable industries. The defining characteristics of the defence industry, such as strong institutional forces, a long history of close cooperation with government agencies, the manifold influential roles of these agencies as regulator and customer, can be compared to some degree with other industries, such as state-run health systems, or the "security" industry. Defence can be seen as a critical case of such highly regulated industries with a single (or small number of) centralised buyer(s). In essence, the identity and institutional literatures are being synthesised with the Capabilities

literature to identify the effects the former have on capability development and the diffusion of technological innovation between sectors.

Goals: The creation of a theoretical framework, which explains the relationships between certain firm-level characteristics and the likelihood and success of DUT2; to refine this framework to be feasibly expanded with testable hypotheses

5) *Hypothesis development*: In order to test the theory of DUT2, a set of testable hypotheses was created, which can be tested by means of a quantitative study based on survey data.

   Goals: To generate a set of testable hypotheses to test the theoretical framework proposed in 4)

6) *Survey instrument design*: A survey questionnaire was designed using a combination of scales designed for this study and scales based on previous studies. Factor analysis was employed to test the reliability of these scales. The survey instrument was designed through an iterative process of collecting feedback from industry experts to optimise the clarity of language and validity of the constructs. Initial testing and piloting was also used to ensure respondents comprehension. Two versions of the survey were created, a long version and a short version. The long version has been used in face-to-face interviews, and contains questions relating to specific DUT2 projects. It was also used in the initial implementation phase of the survey. It is however time consuming, which had a negative effect on response rates. The short version was finalised after analysis of the results of the initial implementation of the long version, and several poorly-performing scales were dropped. The short version was designed with the express purpose of obtaining a high response rate by focusing on the well-performing, firm-level scales. It is critical to note the difficulties in obtaining responses from the targets of this survey. Senior managers in defence firms may be reluctant to disclose information relating to the technologies they develop in the defence context. This can be due to cognitive constructs extant in the industry, or due to firm-wide policies stipulating that employees may not respond to questionnaires focussing on their technology and operations. In fact, several respondents stated that they were bound to MOD regulations to this effect.

   Goals: To create a feasible, efficient survey, specifically adapted to the demands of surveying senior managers of defence suppliers

7) *Survey implementation and data collection*: The survey was transcribed in *MS Word* .doc form, and into the online survey software package *Limesurvey*. The online version was used as the primary delivery mechanism for the survey. A list of contacts was acquired from the trade association A|D|S. This included senior managers from the ca. 500 applicable member firms of the trade association. Difficulties in obtaining responses were predicted and did in fact present themselves. In order to counteract the reluctance to respond, many actions were taken to add legitimacy to the survey. Firstly, the *Limesurvey* mailing shots were conducted using the Imperial College smtp service, allowing for an Imperial College sender address. Secondly, the survey was hosted on a website which was secured with SSL/TLS. Thirdly, the cover letter of the survey explicitly stated that all responses would be kept anonymous, and that no references would be made to individual replies. Including the term “Commercial in Confidence” throughout the survey reinforced this point. This wording was chosen as it was suggested by one expert who was consulted on the project, as it is a recognisable term

relating to sharing information with public bodies, such as universities, and may provide a certain level of protection. It must however be added that the questions were almost exclusively designed as to not arouse any sensitivities in the respondents. The *Limesurvey* invitation email also included a link to the .doc version of the survey, in order to avoid any additional reluctance due to security associated with web-related content.

Goals: To administer the survey in such a way as to minimise the reluctance of potential respondents to complete the survey; to efficiently collect responses by leveraging email and online questionnaire software; to provide alternative response mechanisms if the online version is not favoured.

8) *Data analysis*: The survey data was analysed using the statistical software package *Stata*. probit models were applied to test hypotheses relating to factors which influence the likelihood of DUT2 from defence to non-defence applications and vice versa. Traditional linear regression techniques were employed to test hypotheses relating to firm's aims to strategically reorient away from defence activities.

   Goals: Use of statistical techniques to provide a quantitative empirical analysis of the survey data; test hypotheses generated through interviews with experts and literature review.

9) *Conclusions and Discussion*: Results from the data analysis phase were interpreted and put into the context of the wider literature and expert opinions. Discussion and implications sections were written to reflect the conclusions generated from this interpretation.

   Goals: To provide empirical evidence for the advancement of theory and to inform industry practitioners; to package this information in an accessible, impactful concise manner.

4.2 Sample

The sample for the DUT2 survey was drawn from the Register of A|D|S Group. Their entire database comprises around 900 member firms active in these industries.

The database constitutes a group of firms, which is very heterogeneous regarding size. It includes very large companies such as BAE Systems with over £30 billion revenue per year, but also many relatively small SMEs. A wide range of technological fields is also represented, however with a focus on manufacturing firms and therefore engineering and the physical sciences.

The A|D|S Defence registry is divided into three sections: 1) Full systems manufacturers; 2) Equipment and component manufacturers and 3) Service providers. As this study deals with the development and transfer of technologies, the third group has been omitted from the sample. In

addition, several firms not engaged in R&D, technology maturation or technology demonstration have also been excluded.

The database of contacts provided by A|D|S includes the nominated contacts responsible for the interaction between the firms and A|D|S itself. In the majority of cases this includes the heads of the companies. In the case of most SMEs, these contacts are ideal candidates to complete the questionnaire. In the case of the larger firms, several board-level individuals are included in the database. In such cases, the most relevant first contact was selected on the basis of knowledge of the technology development and transfer activities.

First contact with the firms was made in the form of an email from A|D|S's commercial policy coordinator, sent directly to the contacts' email addresses. The email included an introduction of the principle investigator, a statement of support for and endorsement of the project, and a request for the recipient to complete the survey, as it would be beneficial to the Group. The email also included the request for the recipient to provide an alternative contact if this would improve the quality of the response.

4.3 Survey Design and Implementation

This section will outline the various steps in the process of survey design and execution, and justify why these steps were taken in relation to the design of the overall study. It will follow a structure developed in Pinsonneault & Kraemer (1993), with specific focus on elements of research design, sampling procedure and data collection.

This structure confronts the researcher with several questions relating to the justification and effectiveness of carrying out specific tasks in the course of implementing the survey, and making conscious decisions relating to these tasks.

4.3.1 Research Design

Initially, it is imperative to be clear as to the type of survey, which is to be conducted. In this case, a cross-sectional survey was executed. Although this limits the scope for causal inferences, as it does not allow the detection of temporal priority, a cross-sectional survey can still be used to generate valuable data. Additionally, the time and cost associated with carrying out longitudinal studies is a

significant barrier, as is the pursuit of repeat responses over time in an environment such as the defence industry, which already poses significant challenges to response rates.

Secondly, it is imperative to be clear on the unit(s) of analysis, which the study addresses. This study focuses on firm-level factors predicting firm-level outcomes. This unit of analysis is considered both in hypothesis development and in sampling procedures and data collection. With the proposed sampling procedures, however, it is clear that a survey questionnaire will be completed by individuals, and that this must be considered when using a firm-level unit of analysis. The section on sampling frame will demonstrate that a consistent, targeted approach can be used to alleviate this potential for disturbances.

Thirdly, it is necessary to ensure that the targeted respondents are representative of the unit of analysis. In this case, the respondents are drawn from a list of members of a defence industry focussed trade association. Individual respondents are selected from senior management positions ensuring they are knowledgeable regarding their organisations' strategy and the DU phenomenon. Also, the survey introduction describes the unit of analysis.

Next, careful consideration must be taken to produce clearly-stated, testable hypotheses, and that these are adequately categorised into constructs, which are addressed in the questionnaire. They must again also be conformant with the unit of analysis. This survey employed a mixture of previously used multi-item scales, as well as scales constructed for this study. Validation of the instrument in the early phases showed that most scales were performing well. Poorly performing scales were dropped from the subsequent analysis. The hypotheses are clearly firm-level in nature and adequately measurable by the survey instrument.

Finally, it is imperative to remain aware of the planned subsequent data analysis phase, to ensure the survey instrument is adequate to collect all necessary variables. This was a significant issue in the execution of this survey, and any variables available from secondary sources were not included in the survey, to reduce the length of the questionnaire. We focused on collecting data relating to the theoretically important and interesting concepts, which are not available elsewhere. Although proxies may be potentially available for some of these measures, these tend to be imprecise (Grant, 1996). One contribution of this study is the incorporation of these measures as they are theoretically interesting, although, as Spender & Grant (1996) express, often the theoretically most interesting concepts are the most difficult to measure (Sapienza et al., 2004).

4.3.2 Sampling Procedures

One particularly relevant finding from Pinsonneault & Kraemer (1993) is that many studies employ underdeveloped or inadequate sampling frames. Before sampling itself can commence, it is necessary to ensure that the frame is in itself representative of the population to which conclusions are to be generalised. Often, studies are based on sampling frames that are either ill-defined, or in fact potentially mis-targeted due to issues pertaining to convenience. In the case of this study, it was fortunate that the sampling frame combines representativeness and convenience, as the membership of the UK's largest defence-focused trade association can be used as a reasonable indicator for a firm involved in the industry. This relationship was discussed with a senior Defence Economics academic in a face-to-face meeting. By additionally pruning away firms, which were purely involved in services in the defence sector, the sampling frame is set so as to ensure representativeness. In essence, it can be said that this study employs complete sampling of the entire set of firms which are members of A|D|S, but are not solely involved in the service sector.

It must be noted that there are a number of UK firms involved in the defence industry, but are not A|D|S members. However, due to the wide spectrum of A|D|S members across all defence-relevant sectors, this is unlikely to affect the representativeness of the sample. In part, these firms will include organisations with minimal involvement in defence, who may either have no focus on the industry - solely generating opportunistic sales of generic products, or potentially firms further up the supply chain, who are not necessarily aware of their involvement in the industry (as shown in Hartley, 1997).

Regarding the representativeness of the sample itself, significant effort was put into not only removing irrelevant firms from the study, but to also ensure that the individual respondents held senior management posts within the target firms, so as to ensure they 1) possessed the requisite knowledge regarding the firm's strategic orientation and operations, as well as the DU-concept, and 2) were comparable to each other with regard to their position within their organisation. In this case we can ensure a good degree of representativeness and data quality when posing questions regarding the perceptions of senior managers (i.e. influential decision makers) within defence firms in the context of DUT2. In essence, we are equating the perceptions of Top Management Teams to the firm-level attributes, which we seek.

Finally, sample size and response rate had been predicted to be one of the most difficult challenges of this methodological approach to this research. As mentioned, the complete sample of relevant A|D|S members was targeted for the survey, totalling 611 organisations.

4.3.3 Data Collection

Data was collected using an online survey. This method ensured an efficient and effective opportunity to gather a large number of responses at low financial and time-related cost. In order to ensure no responses were lost due to respondents' potential to refuse to access the survey due to cookies, a downloadable *MS Word* .doc file was made available, and a link was inserted into the invitation email. Additionally, some responses were gathered in face-to-face interviews when the opportunity arose.

A large amount of time and effort was invested in order to maximise the response rate, by the following means:

- Negotiating access to the A|D|S members' contact database, to reduce the perception of "cold-calling"
- Clearly stating that the survey is part of a publically funded, academic research project
- Clearly stating the various degrees of involvement of Imperial College, EPSRC and A|D|S
- Emphasising the confidentiality with which the data will be handled, also including the wording "commercial in confidence" to demonstrate attention to detail regarding data protection and security when dealing with a public institution
- Ensuring the maximum possible level of brevity within questions without diminishing the quality of the measures or clarity of language
- Specific attention to potentially discouraging questions which may cause respondents to discontinue the survey due to sensitive information (a major component of the validation phase with industry experts)
- Reduction in the number of questions in the short form version of the survey by removing poorly-performing measures, also resulting in a positive effect on the response rate

Despite these steps, obtaining a sufficient response rate was challenging, due to the relatively small sample, combined with the cognitive barriers apparent when approaching the defence industry, and the potential for issues of sensitivity regarding the firms' technological capabilities, operations or strategic orientations.

In order to ensure the quality of the survey, and to improve wording, clarity and structure, a validation phase was carried out prior to execution of the survey. This involved several interviews with industry experts, with backgrounds within industry and academia. This phase did not lead to substantial content changes; however several wording changes were made.

4.4 Questionnaire design

This section will now provide more detail regarding the development of the survey instrument. A survey questionnaire was designed and implemented with the support of the A|D|S Group, a trade association advancing the UK Aerospace, defence, security and space industries. A|D|S provided feedback on the design of the questionnaire, and access to its contact list. As mentioned above, two versions of the survey were created, a long version (Appendix 2) and a short version (Appendix 1). Due to the significant difficulties in gaining responses to surveys in this industry, the short version was used to gather data for the quantitative analysis.

The following will provide an overview of the operationalisation of the measures referred to in the theory section. As will be discussed, several constructs were not included in the short version of the survey.

Most variables were measured on multiple-item scales, using a Likert scale (unless otherwise stated). Some items were developed specifically for this study, although others are based on previously developed measures. All statement style items were measured on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree.

4.4.1 Short form questionnaire

The short form questionnaire focuses solely on firm-level characteristics. In particular, it enquires as to the organisations defence sector-specific identity, and the adaptation of its business functions and employees to the defence industry. Also included are measures regarding technology orientation, cost efficiency, and quality-to-cost ratio of the firm's products and services (i.e. ranging from aiming for highest quality regardless of cost, to focus on low cost production).Table 8 shows the scales and alphas in the short form questionnaire:

Strength of Defence sector-specific Identity	**α**
Our management sees our organisation first and foremost as a defence supplier.†	0.828
Our important stakeholders (e.g. suppliers, customers, etc.) see us first and foremost as a defence supplier.	0.8341
Our employees identify strongly with the values of defence business.	0.8614
In our communication with important stakeholders, we consistently portray ourselves as a defence supplier.	0.8349
We see ourselves as supporting the national defence objectives rather than being purely profit-oriented.	0.8725
We employ ex-service personnel at senior management levels.	0.9066
Test Scale	0.8785
Technological Excellence	**α**
We build upon proven technological breakthroughs made by other organisations.	.
We strive to achieve technological leadership in the markets in which we compete.*	0.6775
We emphasise technological superiority to differentiate out new products.*	0.6875
We aggressively adopt new technologies in the early phases of their introduction.	0.7679
We focus heavily on cost efficiency and strive to be a very "lean" organisation.	0.7693
We always prioritise quality over cost.	0.7862
Test Scale	0.7814
Human Asset Specificity	**α**
Our organisation's market knowledge is focused specifically on the defence industry	0.8559
Our employees' market knowledge and skills are tailored to meet the specific conditions of our defence business.	0.8501
It would be very difficult for our employees to transfer market knowledge acquired in our organisation's defence business to applications outside the defence sector.	0.9062
Many of our employees can be considered specifically defence sector-specialists.	0.8437
We often hire new employees with a strong record in the defence sector.	0.859
Our employees are intrinsically motivated to work on defence sector projects.	0.857
Test Scale	0.8838
Business Function Specificity - Product Adaptation to Defence	**α**
Our research activities (e.g. selection of technological fields, fundamental research).	0.8431
Our development activities (e.g. meeting defence customer specifications, product/service customisation, integration into defence systems/platforms).	0.7122
Our product design activities.	0.7461
Our manufacturing activities.	0.8494
Test Scale	0.836
Business Function Specificity - Service Adaptation to Defence	**α**
Our marketing/customer relationship management activities (e.g. tendering, contracting, identification of customers' needs).	0.8617
Our distribution activities (i.e. we sell mainly to MOD/other defence agencies or within defence supply chains).	0.8757
Our after-sales support activities (e.g. monitoring, maintenance)	0.8495
Our other service activities (training, consulting, financing)	0.9034
Test Scale	0.9018
† dropped due to poor performance	
* these items also constituted a 2-item scale of Technology Orientation with a scale alpha of 0.9154	

Table 8: Scales, items, scale- and item-alphas for the short form questionnaire

Dependent Variables: Occurrence and directionality of DUT2

Respondents were asked to state whether their firm had transferred technology from defence to non-defence applications, or vice versa. Therefore, there were four possible outcomes: 1) The firm had never transferred technology in either direction, 2) the firm had transferred technology from defence to non-defence applications, but not vice versa, 3) the firm had transferred technology from non-defence to defence applications, but not vice versa, and 4) the firm had transferred technology in both directions.

Initially these responses were coded into two separate binary variables, one for each direction of DUT2.

Dependent variable: Strategic reorientation to non-defence activities

This measure constitutes the difference between two statements on seven-point Likert scales. The first statement relates to the firm's intent to engage in non-defence markets in the future, and the second relates to their past engagement with non-defence activities. The difference signifies the shift in their strategic orientation.

Strength of defence industry-specific identity

The defence sector-specific identity (ID) scale was created for this study. Six items are included, and pertain to perceptions of senior management and important stakeholders regarding the firm's belonging to the defence sector identity domain. It also includes items pertaining to communications generated by the firm to be disseminated externally, and the employment of ex-service personnel at senior management levels.

Technology Orientation

The technology orientation (TO) scale aims to capture the strategic focus of the target firm on technological sophistication and superiority. The four-item scale was developed from Jeong et al. (2006), based upon the work of Gatignon & Xuereb (1997) and Song & Parry (1997). The items refer to the firm's willingness and determination to adopt and deploy innovative technologies early in their life cycle, and the firm's dependence on such technology, which is acquired from external sources.

Human Asset Specificity

Differing opinions regarding the specificity of human assets within the defence context were discovered during the exploratory phase. In particular, several authors in the DUT2 literature remarked that there are difficulties in transferring knowledge acquired in the defence sector to other sectors, and that there are various cognitive barriers associated with employees' intrinsic preference for defence-related projects. However, several interviewees stated that the essential technical skills are applicable beyond the defence sector (if there is demand for the particular technological field).

The human asset specificity (HAS) scale seeks to address this issue, by including items relating to the transferability of technical knowledge, and also referring to cognitive aspects relating to employee motivation to work on defence projects and not non-defence projects. The scale is based on a similar scale employed by De Luca & Atuahene-Gima (2007), modified to be applicable to the defence sector context.

Procedural Asset Specificity

This group of questions breaks down the firm into eight functions, and asks the respondent to rate each the adaptation of each individual function to the defence industry. The functions are: 1) Research activities, 2) development, 3) design, 4) manufacturing, 5) marketing & customer relations, 6) distribution, 7) after sales support and 8) other service activities (e.g. training, consulting, financing).

The first four functions can be seen as product dimensions (ProDim), whereas the subsequent four are service dimensions (SerDim). This structure was taken consciously, in order to explore the notion that the locus of the defence specific rigidity could be located in one or the other of these dimensions.

4.4.2 Long form questionnaire

As mentioned earlier, the long form questionnaire included an additional section with project-level questions. It also included several additional firm-level scales. This section will first deal with the firm-level scales, which were subsequently dropped, then it will describe the project-level variables included in the additional section.

Secrecy / confidentiality

There is a common perception that the defence industry is heavily secret, and separated into its own silo. Although this is surely true of several sensitive industries (particular NRBC – Nuclear, Radiological, Biological and Chemical), we argue that the importance of commercial secrecy is also held in such high regard by commercial entities with no defence involvement, if they define their capabilities along the lines of their technical knowledge and technological superiority [to patent or not to patent].

However, if a defence firm does engage in activities that are regulated by government, and are deemed a strategic priority, or as sensitive and dangerous, these firms will be subject to additional forces, which may influence the likelihood of technology transfer. This important effect is of great research interest; however, it must be stated that effect of the transfer of such technologies out of the defence environment is likely to be detrimental to national security and in fact highly undesirable to the wider population.

At this point it is necessary to explain that the degree of secrecy/confidentiality regarding a firm or project is not an operationalisable construct within the context of this work. This is due to the fact that a firm may be engaged in sensitive work, and may in fact be inhibited in technology transfer activities by the barriers government control and regulation may cause (Petroni & Verbano, 2000). However, as the level of secrecy and government control increases, at some point any respondents or other organisational members will in fact deny the existence of such restrictions [X-list etc.] (see Figure 16). In addition to this, even prior to this shift to non-response, this question can lead to misreporting. This is due to the fact that respondents are naturally likely to be more unwilling to respond to such a survey if they are cognitively adapted to behaviours associated with the sensitivity of their work (either on a personal/individual level, or as part of an organisational policy).

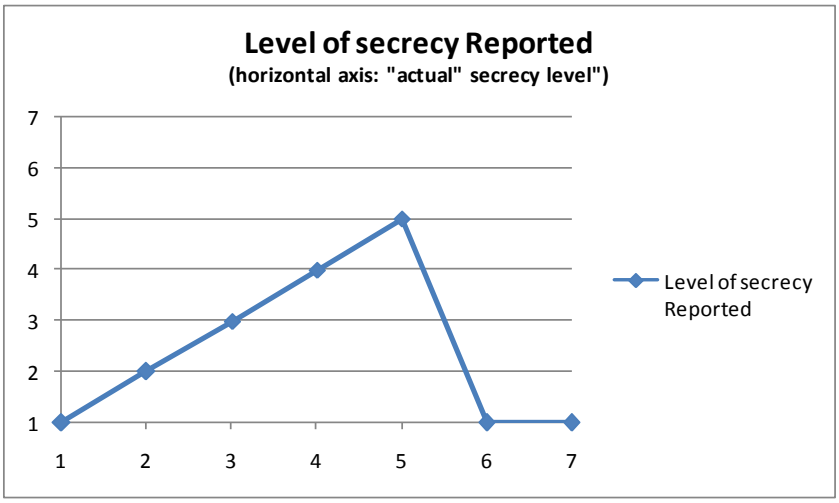

Figure 16: Actual versus reported secrecy level

Therefore, the variable concerning the degree of secrecy/confidentiality was dropped from the final analysis.

Focus on aesthetic design

The long form survey included a scale of the organisation's focus on the aesthetic elements of design. This rather unintuitive avenue of inquiry arose due to several interviews and other statements from experts, who described some differences in designing products for military use versus civilian, particularly consumer use. There is a conceptual continuum between a focus on functionality and ruggedness, which is imperative for military equipment, and aesthetic aspects that are mostly ignored by firms designing defence equipment.

The aim was to identify if a lacking capability in this area was a significant barrier to DUT2. This was always considered an outside chance and unfortunately the measure did not function as hoped. Several respondents noted the items seemed out of place, and the scale itself did not perform well.

We do however believe that future research into this concept is not without merit. Although the B2C market is by no means a major focus of DUT2, it must be noted that consumer electronics markets are becoming increasingly competitive regarding these aesthetic elements of design.

Project-level variables

The following variables were included in an additional section which was only included in the long form questionnaire. As such, only several dozen responses were collected, and the project-level analysis could not be carried out with the same quantitative methods used for the abovementioned firm-level variables. They do however shed some light on factors influencing the success of initiated DUT2 projects.

Market similarity

Market similarity refers to the degree of difference between the target market and the defence sector. As the firms engaging in DUT2 are engaged in the defence sector, they are likely to be affected by exposure to the defence-specific institutional forces present in this sector. Therefore, they are likely to be adapted to this sector. We suggest that this leads to the firm being subject to a defence sector-specific cognitive framework, and that they also build defence-specific capabilities, which will be optimised to improve performance in the defence sector.

It is hypothesised that the higher the degree of market *dissimilarity*, the less likely the firm will be to engage in a DUT2 project, due to the market uncertainty associated with the project.

We also suggest that a high degree of market *dissimilarity* will have a negative effect on DUT2 success. This is due to the fact that the firms will not be effectively adapted to this new environment, therefore decreasing the likelihood of success while operating in such markets. This could be due to a lack of market knowledge, as well as the fact that the firm is likely to be adapted to the defence sector in particular, which is regarded as an insular environment, characterised by strong institutions and unique practices (Hartley, 2007).

Several studies of cases of DUT2, (e.g. Brown & Franck, 1998) show that DUT2 is more common when the target market is similar, in this case involving transfer to law-enforcement or medical applications, both highly regulated markets with a high degree of government involvement.

Required level of customisation

This measure intends to capture the level of customisation required in order to transpose a technology from a military setting or application to a civilian application. Increasing application similarity decreases the required level of customisation, as the civilian application is relatively similar to the original military application, and vice versa.

This concept does not refer to a requirement for scientific and engineering R&D work, but to a difference in the adaptation of an existing technology. The defence firm wishing to engage in DUT2 must understand the needs of the civilian customers, and be able to sell a product (or service) which meets their requirements. It also involves the creation of infrastructure to support the new product (or service). Teece (1986, p.285) states that "innovators with new products and processes which provide value to consumers may sometimes be so ill positioned in the market that they necessarily will fail." In this case we argue that the defence firm may not be able to take advantage of its technological capabilities as they are not able to effectively customise the technology to the needs of the target market customers.

We expect that the required level of customisation with respect to the DUT2 project will be negatively associated both with the likelihood of the firm engaging in a DUT2 project, as well as the success of an initiated project. This is due to three reasons: First, an increased level of required customisation will give rise to increased costs, thereby increasing the barriers to DUT2. Second, an increased level of customisation will bring with it an increased level of market uncertainty. Third, the need for customisation implies greater service intensity and associated need to invest in building and maintaining service functions in the civilian market. Such investment would distract focus and attention from the core military market and would likely face resistance within the company. Combined, the three mechanisms increase the challenges that the firm will face in transposing the technology from its existing military application to the proposed civilian application. The magnitude of these challenges will be positively correlated with the level of required customisation.

If the required level of customisation increases, it is likely to strengthen the negative effects of defence sector rigidities on the likelihood and success DUT2. If the required customisation is high, defence-specific rigidities will operate as a potent deterrent against an investment of effort into DUT2. On the other hand, if the required customisation is minimal, little additional effort will be required to try out DUT2 projects even if the firm would experience defence-specific rigidities. A firm with highly optimised capabilities to the defence sector context is likely to encounter a higher degree of market uncertainty when engaging in civilian markets. Therefore the following three arguments must be seen as manifestations of the effect of increased required customisation level in the context of the relationship between defence sector-specific rigidities and DUT2.

If the level of required customisation is known to be high before the decision to engage in DUT2 has been made, the associated costs will affect management decision-making with regard to whether or not to engage in a DUT2 project. This is because higher costs will reduce the attractiveness of the project in the eyes of the management.

The required customisation will also bring with it market uncertainty associated with the project. This leads to increased anticipated costs, some of which will be foreseeable while others are not. A higher level of market uncertainty alone will reduce the likelihood of a firm engaging in a DUT2 project.

In addition, the market uncertainty will have a negative effect on DUT2 success, as these challenges, whether anticipated or not, will lead to an increase in costs associated with the project, or may even present an unforeseen, insurmountable obstacle.

This effect may interact with defence sector rigidities due to the fact that this uncertainty will be higher if the firm has little experience in this market, or similar markets, and there is a resulting misalignment of capabilities to the target market, and a limited understanding of its nature.

Technology maturity

There are numerous examples of technologies for which, although a civilian commercial application can be imagined, this application does not materialise due to the high cost of the R&D required to bring the technology to market. Military spending is known to have been essential in "bridging the funding gap" in many such cases as mentioned. Military procurement is often driven by factors other than the return on investment, most obviously the acquisition of a relative advantage in military capability. This advantage can be gained by possessing a technological advantage on the battlefield (Middleton et al*.,* 2006).

Murphy & Edwards (2003) refer to the "cash flow valley of death" between research in government agencies, and their subsequent development to be commercialised in the private sector. Within the defence sector, the *Technology Readiness Levels* scale (TRL) is widely used. This measure of maturity of the technology in question will be used to capture how well developed the technological foundation, i.e. the transfer object, of the DUT2 project was before the project was initialised. Essentially this metric can be used to measure how far from the market a technology is. The TRL scale is illustrated in Figure 17. This shows the nine TRL levels and their descriptions (Great Britain, Ministry of Defence, 2009a).

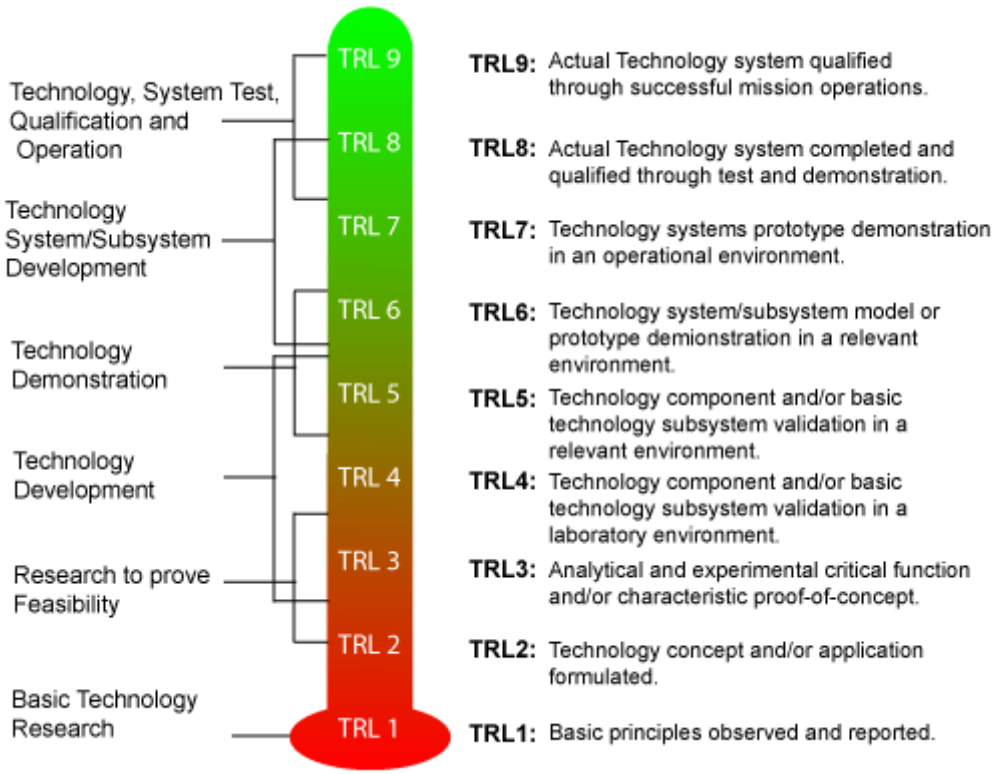

Figure 17: The MOD Technology Readiness Level scale (Great Britain. Ministry of Defence, 2009a)

As this scale is widely used in the defence sector, defence firms will be well aware of it. This scale was used to measure the level of development of a DUT2 transfer object at the inception of the DUT2 project.

It is argued that a DUT2 project where the DUT2 transfer object is highly developed, i.e. it has a high TRL, will have a positive effect on DUT2. This is due to the fact that previous military funding has contributed to the development of the technology, therefore reducing the necessary investment required for the development process. It will also imply a reduction in technological uncertainty associated with the DUT2 process.

After a certain point, military spending is likely to be geared toward the development of the military application of a technology, which will reduce the positive effect of this spending on DUT2. Effectively, after a certain point, the trajectory of the technological development will move away from fundamental proof of concept etc., to adapting and inserting the technology into military operations, potentially moving it away from the civilian application.

This is not to be confused with the requirement for customisation, which is a measure of the dissimilarity in the military vs. the civilian application, and the subsequent requirement of the firm to

customise to meet the market needs. Technologies can be highly mature (TRLs of 8 or 9), but require vastly different levels of customisation to meet two different applications. This is also the case of immature technologies, whereby the future trajectory of their R&D process may lead to any level of technological dissimilarity, and therefore required customisation for the purposes of DUT2.

For example, if a military transport helicopter which is in-service is to be transposed to a civilian application, the required level of customisation will be extremely low as it will not need to be significantly adapted to the civilian application. At the same time, the TRL will be very high, as all components etc. will be fully developed and tested.

However, a military radar system is likely to be a complex technological system which is integrated into military command and control systems, as well as into its platform (e.g. fighter aircraft, air-defence destroyer). It may be integrated into e.g. weapons guidance systems etc. If a firm with the technological capability in military radar systems were to wish to leverage this capability in civilian markets, the transfer object would be considerably lower down the TRL scale. The technological foundation underlying the DUT2 process would be significantly less developed. The DUT2 process would include significant further R&D work.

An increasing level of maturity of a pre-existing technology, technological capability, or technology-based- product or service (constituting the transfer object) will decrease the costs and uncertainty associated with a DUT2 project, and therefore increase the likelihood of engagement in such a project. It will reduce the associated technical uncertainty associated with the project, therefore having a positive effect on its success.

4.5 Model Specifications

The survey responses were collated, cleaned and appropriately coded for statistical analysis using the statistics software package *Stata*. We ran three models with numerous specifications for each model. The following three models were constructed:

1) A probit model predicting the likelihood of DUT2 from defence to non-defence
2) A probit model predicting the likelihood of DUT2 from non-defence to defence
3) An OLS model predicting the level of strategic reorientation toward non-defence activities

Model 1) specifications- included strength of ID, Technological Excellence (TExc), Human asset specificity (HAS), product dimensions (ProDim) adaptation and service dimensions (SerDim)

adaptation. Additionally, various controls for firm size and liquidity ratio were included, drawn from Bureau van Dijk's FAME (Financial Analysis Made Easy) database. First, a full model including all of the direct effects of these variables was estimated, then the interaction between TExc and ID was introduced, then subsequently the variables with no significant effect were dropped. This process was carried out to ensure robustness of the coefficients and p-values across the differing specifications.

Model 2) was similarly specified, however with the TO variable in place of the TExc scale. This change was executed to capture the differing technological, quality- and cost-related demand conditions between the defence industry and the wider economy. More detail on this theoretical choice can be found in the theory section.

Model 3) included TExc, ID, but also percentage revenue generated from MOD sales (MODSales), and percentage revenue generated from overall defence sales (DefSales), as well as the same controls. This was also initially set up as a full main-effects model. Then the interaction was introduced, and subsequently the model was estimated without the controls and non-significant scales.

The following section will report the results from these three models in turn.

5 Analysis and Results

This section will report and analyse the results from the three models outlined in the previous section. It will begin a section reporting descriptive statistics, and continue with the probit model predicting the likelihood of DUT2 from defence to non-defence, will then continue with the probit model for non-defence to defence, and conclude with the OLS model predicting strategic reorientation to non-defence activities.

The first two models were also run as logit models, as a robustness test, with no significant differences in significance.

It is critical to note at this point that our study is limited by a relatively low response rate from an already small sample. The underlying data for the probit models has 71 observations, and the OLS model is restricted to 67 observations, due to several non-responses regarding firm's revenue source breakdown. This must be taken into account when making conclusions from the following results. This is one major justification for combining the quantitative analysis with expert interviews in an iterative process (Kim & Miner, 2007). At all stages, hypothesis development was supported by in-depth discussions with experts, and the results were compared in detail to the statements collected in the interview stages.

5.1 Descriptive statistics

The survey was emailed to a total of 611 email addresses, of which 42 proved to be no longer current. Alternative contacts were sought for these "bounced" emails, leading to a total of 583 successfully sent emails. During the long form questionnaire implementation phase, several respondents were logged as having accessed the survey, but did not proceed to complete it. This was one driver in following up with the shorter version. Several additional responses were incomplete to such a degree that they were not included in the final analysis.

After cleaning and following up for missing responses where possible, a total of 71 usable responses were used for the subsequent analysis. This represents a response rate of 12.2%. Under the circumstances this is an acceptable response rate, as willingness to participate was perceived to be low. It is likely that it was significantly raised by the steps taken to ensure legitimacy of the survey, and the reduction in length for the short form survey.

Four respondents of the 71 did not include responses regarding the breakdown of their revenue sources (% MOD, % defence, % exports). We were unable to gain these figures through follow-up or secondary data sources. Therefore, the *N* in the third model to be presented is equal to 67.

	1	2	3	4	5	6	7	8
1 DUT2 defence to non-defence	-							
2 DUT2 non-defence to defence	0.4516*	-						
3 Strategic Reorientation	-0.0294	0.1915	-					
4 Organisational Identitiy	-0.0358	0.0343	0.2663*	-				
5 Technological Excellence	0.1906	0.4208*	0.4557*	0.1950	-			
6 Human Asset Specificity	0.0007	-0.0035	0.2480*	0.8562*	0.1083	-		
7 Product Dimensions	0.1779	0.2907	0.3384*	0.6470*	0.2661*	0.6435*	-	
8 Service Dimensions	0.0585	0.1518	0.1726	0.8312*	0.2816*	0.7728*	0.7242*	-
Mean	0.6478	0.74678	0.0035	0.0067	0.0397	0.000	0.0067	0.0073
S.D.	0.4810	0.4381	1.0066	0.8005	0.9482	1	1.0054	1.0052
Min.	0	0	-4.2616	-1.4502	-4.1175	-1.5864	-2.0258	-2.0057
Max	1	1	3.7603	1.4584	1.3951	2.2203	1.5884	1.4651
*p <0.05								

Table 9: Correlation matrix, means and ranges

5.2 Defence to non-defence DUT2

Table 10 shows that in the main-effects model, it cannot be said with confidence that the coefficient relating to defence identity strength is not zero. This result in itself is surprising, as it would seem to indicate that a strong defence sector-specific identity does not affect the likelihood of DUT2 from defence to non-defence. Therefore, hypothesis 1a is not supported. However, the expected negative sign is present on the (albeit very small) coefficient.

DUT2 D to non-D	Model 1	Model 2	Model 3	Model 4
ID	-0.00243	-0.0588	-0.295	-0.0856
	(-0.00)	(-0.12)	(-0.69)	(-0.40)
TO	0.470*	0.414*	0.406*	0.459*
	(-1.67)	(-1.69)	(-1.66)	(-1.92)
IDxTO	-0.708**	-0.707**	-0.656**	-0.713**
	(-1.98)	(-2.18)	(-2.08)	(-2.28)
HAS	-0.166	-0.00166	0.0569	
	(-0.47)	(-0.01)	-0.18	
ProDim	0.41	0.336	0.23	
	(-1.38)	(-1.18)	(-0.89)	
SerDim	-0.0946	-0.208	-0.0166	
	(-0.24)	(-0.55)	(-0.05)	
LqR	-0.123	-0.218		
	(-0.63)	(-1.20)		
Turnover	15.07			
	(-0.84)			
Employees	2.975			
	(-0.45)			
_cons	3.449	0.406**	0.396**	0.404**
	(-1.22)	(-2.39)	(-2.35)	(-2.4)
N	71	71	71	71
t statistics in parentheses				
*p<.10, **p<.05, ***p<.01				

Table 10: Probit model of DUT2 from defence to non-defence

Also, the table shows that technology orientation does have a significant positive effect, which constitutes evidence for the argument that defence firms may be able to leverage their technological advantage (partially funded by and otherwise supported by defence agencies incentivised to act as early adopters of new technology). With this result, hypothesis 2 can be supported.

It cannot be confidently asserted that the coefficient regarding human asset specificity is non-zero. Therefore, hypothesis 5 is not supported. Although several sources in the literature argue that a high level of employee skill specificity may hinder DUT2, several interviews have shown that this is not likely to be the case. This result could therefore potentially be seen as preliminary evidence that this previously held belief must be revised.

The next column of Table 10 shows the results from the second specification, where the interaction between defence specific identity strength and technology orientation has been included. The coefficient of this interaction is negative, and significant, indicating that a strong defence sector-specific identity weakens the positive effect of technology orientation on the likelihood of DUT2. It can be argued that the technology orientation is in effect a necessary condition of sorts in this model; however, it is not sufficient, as a strong defence sector-specific identity will inhibit DUT2, even in the presence of a strong technological foundation. This supports hypothesis 4a.

Product dimensions and service dimensions of business functions also have no significant effect of DUT2, thus not supporting hypothesis 6. Again, this is surprising, in that it would be expected that a strong adaptation would hinder efforts to transfer technology to non-defence applications. However, these results would seem to support to premise that a significant portion of the defence-specific rigidity is cognitive in nature and located in the top-managerial domain, as well as in sector-specific managerial competencies.

We also control for firm size (employees and revenue) as well as the firm's liquidity ratio; however, there is no significant effect related to these variables.

5.3 Non-defence to defence DUT2

Table 11 shows the results from a model, which was set up similarly to the model in Table 10, however, with the DUT2 from non-defence to defence used as the dependent variable. The significant coefficients have the same sign as in the previous model, as is expected.

As in the previous model, defence sector-specific identity strength does not have a significant effect, such that we do not support hypothesis 1b. Again, this can be considered surprising, however falls in line with the theoretical concept that the identity itself does not constitute a direct effect, but as a moderating effect.

We see that Technological Excellence has a positive effect and is significant, the magnitude of which is robust across specifications, therefore we support hypothesis 3. This constitutes evidence for the positive effect that the focus on the delivery of excellence constitutes a strong positive factor in relation to the likelihood of transferring technology into defence. In essence, technologies developed by these firms can access the demand for such technologies created by defence agencies. These agencies are in the market for high-end technologies, for example in the areas of surveillance and communications. Commercial solutions are often superior to specifically developed defence sector solutions in such fields.

The coefficient on the interaction of defence sector-specific identity strength and Technological Excellence is also significant and negative. This supports hypothesis 4b in that the strength of identity weakens the positive relationship between Technological excellence and DUT2 from non-defence to defence. A firm with a strong defence sector-specific identity is likely to be inhibited by sector-specific cognitive schemas and mental models, as well as structural and behavioural aspects that act to reduce the likelihood of DUT2 from non-defence to defence.

DUT2 non-D toD	Model 1	Model 2	Model 3	Model 4
ID	-0.868	-0.9	-0.491	-0.159
	(-1.28)	(-1.35)	(-0.83)	(-0.64)
TExc	0.940**	0.885**	0.834**	0.905***
	(-2.51)	(-2.5)	(-2.39)	(-2.66)
IDxTExc	-0.697*	-0.682*	-0.650*	-0.897**
	(-1.70)	(-1.78)	(-1.67)	(-2.38)
HAS	-0.276	-0.211	-0.293	
	(-0.65)	(-0.51)	(-0.72)	
ProDim	0.396	0.35	0.447	
	(-1.24)	(-1.13)	(-1.43)	
SerDim	0.625	0.599	0.305	
	(-1.15)	(-1.14)	(-0.65)	
LqR	0.485*	0.404		
	(-1.69)	(-1.5)		
Turnover	-1.233			
	(-0.57)			
Employees	3.559			
	(-1.05)			
_cons	1.207**	0.887***	0.844***	0.857***
	(-2.25)	(-4.09)	(-4.11)	(-4.23)
N	71	71	71	71
t statistics in parentheses				
*p<.10, **p<.05, ***p<.01				

Table 11: Probit model of DUT2 from non-defence to defence

These results also show no evidence of effects of the adaptation of product or service dimensions on DUT2 from non-defence to defence, again not supporting hypothesis 6.

The control variables relating to firm size are also not significant. Interestingly, employees have a positive sign and turnover a negative sign, but due to the large p-values these results do not allow any meaningful interpretation.

We must point out that in the full main-effects specification, liquidity ratio has a positive effect and is significant. The effects of this variable can be conceptualised in terms of a proxy for slack resources, an abundance of which would be expected to function as an enabler for DUT2 projects. We did not however find consistently robust evidence for this effect.

5.4 Firm's shifting focus toward non-defence activities

Table 12 shows the results form an OLS regression using the firm's intent to shift their activities from defence toward non-defence in the future. Principally, three variables appear to be significant in predicting the eagerness to shift.

Strategic Re-orientation towards non-D activities	Model 1	Model 2	Model 3
ID	-0.148	-0.0904	-0.0819
	(-0.49)	(-0.31)	(-0.29)
TExc	0.699***	0.459**	0.463**
	(-4.11)	(-2.47)	(-2.56)
IDxTExc		-0.605**	-0.610***
		(-2.63)	(-2.72)
DefSales	0.118	0.113	0.127
	(-0.48)	(-0.48)	(-0.56)
MODSales	0.412*	0.526**	0.525**
	(-1.98)	(-2.58)	(-2.66)
Employees	0.459	0.178	
	(-0.28)	(-0.11)	
Turnover	-0.416	-0.147	
	(-0.25)	(-0.09)	
LqR	0.0815	0.0715	
	(-0.49)	(-0.45)	
_cons	0.294*	0.396**	0.395**
	(-1.84)	(-2.52)	(-2.57)
N	67	67	67
t statistics in parentheses *p<.10, **p<.05, ***p<.01			

Table 12: Probit model of strategic reorientation towards non-defence activities

Firstly, defence sector-specific identity has no significant direct effect on the intent to grow non-defence activities, therefore not supporting hypothesis 9. Again, technological excellence seems to be a significant influencing factor, leading us to support hypothesis 10. This relationship falls in line with similar explanations for DUT2, i.e. the firms that have such a commitment to delivering technological excellence are more willing to find opportunities in non-defence sectors, and have a stronger belief that they possess potentially valuable technological resources. They are also more likely to have attractive candidate technologies that can be transferred.

It would seem that a defence firm with a focus on high-quality operationally excellent activities involving cutting edge technologies are attracted by the potential opportunities to transfer these capabilities to non-defence applications.

In this case we also see a significant interaction effect between defence sector-specific identity strength and Technological Excellence. The negative sign on the effect can be interpreted in the following terms: A strong sector-specific identity weakens the positive effect of technological excellence on the firm's intent to strategically reorient away from defence, therefore we support hypothesis 11.

The direct effect and the interaction effect are both robust in the presence of control variables for size and liquidity ratio.

Interestingly, it can be seen that the issue of the effect of dependence on defence revenues is relatively complex. The exposure to overall defence revenues would not seem to be a significant driver in this context. This can be explained by the fact that a move to non-defence is a form of diversification, but that such firms have other options in international markets. However, dependence specifically on UK MOD revenues does have a significant positive effect, and in fact a strong one, therefore we support hypothesis 8. This provides evidence for the assertion that the reduction in UK defence spending is having a real effect on firm's strategic orientations in the defence sector, in that it is driving firms to strategically reorient themselves away from defence business.

Table 13 shows an overview of the hypothesis tests indicating whether they were supported or not:

H1a: Strength of defence sector-specific identity will be negatively associated with a firm's likelihood of engaging in DUT2 projects from defence to non-defence	not supported
H1b: Strength of defence sector-specific identity will be negatively associated with a firm's likelihood of engaging in DUT2 projects from non-defence to defence	not supported
H2: Technology orientation will be positively associated with the likelihood of the firm engaging in DUT2 projects from defence to non-defence	supported
H3: Technological excellence will be positively associated with the likelihood of the firm engaging in DUT2 projects from non-defence to defence	supported
H4a: Strength of defence sector-specific identity moderates the effect of technology orientation on the likelihood of the firm engaging in DUT2 projects from defence to non-defence, in that high identity strength will weaken the positive effect of technology orientation	supported
H4b: Strength of defence sector-specific identity moderates the effect of technological excellence on the likelihood of the firm engaging in DUT2 projects from non-defence to defence, in that high identity strength will weaken the positive effect of technological excellence	supported
H5: Human asset specificity, as embodied in the optimisation to the defence sector of employee knowledge and skills, will be negatively associated with the likelihood of the firm engaging in DUT2 projects	no supported
H6: Business function specificity (procedural asset specificity), manifested in highly optimised defence-sector-specific core functions, will be negatively associated with the likelihood of the firm engaging in DUT2 projects	not supported
H7: A strong value placed on secrecy will be negatively associated with the likelihood of the firm engaging in DUT2.	dropped
H8: A higher percentage of revenues from UK MOD will be associated with a stronger intent to reorient to non-defence revenues	supported
H9: A strong defence sector-specific identity will be negatively associated with the intent to reorient to non-defence revenues	not supported
H10: Technological excellence will be positively associated with the intent to reorient to non-defence revenues	supported
H11: Strength of defence sector-specific identity moderates the effect of technological excellence on the intent to strategically reorient to non-defence activities, in that high identity strength will weaken the positive effect of technological excellence	supported

Table 13: Hypothesis test results

6 Discussion

This section will present a discussion based on the results reported above. Once again, it is necessary to highlight that due to the relatively small *N* on which the analysis is based, we have sought to find supporting evidence from interviewees and other secondary sources wherever possible.

The structure of this section mirrors the structure of the analysis and results section. First, the phenomenon of DUT2 is discussed in relation to the factors which influence this transfer. We then go on to discuss the results from the models of DUT2 first from defence to non-defence, then from non-defence to defence. Subsequently, we take the discussion further by examining the factors which influence firms' intent to move toward a higher proportion of non-defence activities.

6.1 Factors influencing the likelihood of DUT2

One major goal of this study was to identify the factors, which influence the likelihood that a firm will transfer technology from defence to non-defence applications, and vice versa. Particular emphasis was placed on the role of the strength of a firm's defence sector-specific identity. These results show that identity is not likely to be directly associated with this likelihood. However, this identity does have a moderating effect on the relationship between technology orientation and DUT2, in that it weakens the positive relationship.

Unlike other studies, this project has generated empirical evidence for this relationship. It can be said that the "wall of separation" (Alic et al., 1992) does in fact exist to a certain extent, but that it functions as a filter, or as a refractive medium that influences the trajectory and delivery of the firm's capabilities. One major potential advantage that defence firms can gain and maintain is access to R&D funding and procurement markets for high technology products and services. The "cash flow valley of death" (Murphy & Edwards, 2003) concept may be involved at this stage, as the firms may be able to conduct R&D which may not have been economically feasible in non-defence markets. Defence agencies, as explained earlier, are willing to fund R&D, and to subsequently procure military equipment that integrates sophisticated technologies. In essence, this external funding and market-making can drive technological development and the creation of technological capabilities in these firms. By developing technologies in such an environment, defence firms can subsequently possess technologies and technological capabilities that would not have been developed in other environments. Thus, provided there is demand for such technologies and capabilities, it can provide the basis for competitive advantage.

There are however barriers to this exploitation. These barriers are partially incorporated in the defence identity construct, which embodies the defence sector-specific cognitive schemas and mental models, which develop and are entrenched in this highly institutionalised, idiosyncratic market. These factors constitute the “wall of separation”, but this study provides evidence of the aforementioned filter- or refraction effect that the wall has on DUT2.

Other barriers to DUT2 suggested in the literature have been tested in this study. Human asset specificity was built into the probit models in this study. However, this factor does not seem to have an effect on the likelihood of DUT2. The argument which is present in some of the literature, namely that defence sector specialists may be cognitively biased against non-defence projects, and therefore may inhibit DUT2 can therefore be disputed. In fact, several interviewees have claimed that the skills and knowledge embedded in these employees could be transferred to non-defence projects. It would seem that a capable engineer with a technical function is not subject to the cognitive rigidities to which top-level managers are subject in their efforts to set firm strategy. This would illustrate the differing effects of defence industry specific firm identity at different levels of an organisation. Unfortunately, this issue was beyond the scope of this study, would however be a valuable avenue for future research.

6.1.1 Defence to non-defence technology transfer

We see from the results in the previous section that the transfer of technology from defence to non-defence applications is affected similarly to technology transfer in the other direction. The major difference in this model is however that the delivery of technological excellence is not an appropriate construct in this direction. This is likely due to the fact that defence agencies are often in the market for technologically sophisticated products, and are willing to pay a premium and act as early adopters. Therefore, it can be argued that the defence market is characterised by a lower level of price elasticity when compared to the average of the wider economy.

Many defence firms in fact communicate narratives which underline this commitment to the delivery of excellence. While a similar approach may be important in the context of transferring technology into the defence sector, in order to gain legitimacy and match the technical sophistication in many defence projects, this construct is not likely to positively affect transfer of technology to the wider economy on average. Several interviewees discussed this issue, in particular making the point that many defence firms are highly adapted to the defence context and are relatively inefficient in terms

of productions costs. Additionally, existing literature as well as interviews have emphasised the point that production runs in the defence sector are often relatively small, also increasing unit costs.

However, technology orientation can be seen to have a positive effect on technology transfer from defence to non-defence. This emphasis on technological sophistication can constitute the foundation for competitive advantage in non defence markets due to the fact that defence firms can often receive funding to develop technologies which may not have been feasible in non-defence sectors. This would support the assertion that the defence sector can be a source of innovative technologies, which may then spread to the wider economy, which is anecdotally captured in the histories of technologies such as the internet, radar and the jet engine. However, the adaptation of these technologies to non-defence uses has usually been linked to a significant increase in scale effects, and decreases in unit costs which increase accessibility. Although it can be argued that many such technologies, such as the jet engine, are still significantly capital-intensive to procure for non-defence uses, the increase in standardisation, larger production runs, and considerable increases in efficiency of production have led to their diffusion into non-defence sectors. Additionally, often such technologies diffuse into markets which can be seen as relatively similar to defence, for example civilian aerospace, security or maritime sectors.

However, the ability to leverage such technologies in non-defence would seem to be influenced with the strength of a firm's defence sector-specific identity. This interaction effect negatively affects the positive effect of technology orientation on the likelihood of DUT2 from defence to non-defence, meaning that the management of a firm with a strong identity in this context is likely to be influenced by cognitive schemas leading to a lack of the realisation of opportunities to diffuse such technologies, and subsequently a lack of success in attempting to do so. As in DUT2 in the opposite direction, this effect of identity can be seen as an embodiment of a phenomenon which has in the past been described as a "wall of separation", however its lack of direct effect on DUT2 seems to indicate that it affects technology transfer in an indirect manner, constituting a "drag" like effect on this transfer, in the presence of other factors which amount to the necessary conditions to successful transfer.

We find no evidence of an effect of human asset specificity on the likelihood of DUT2. This highlights the view, also supported by interviews, that this form of asset specificity does not pose a barrier to DUT2, in either direction. This would then lead to the assumption that the locus of the filter- or drag effect is situated in the managerial domain more than the technical domain. Although there will be technical specialists in the defence sector whose skills are not applicable in non-defence sectors, it would seem that the training and experience engineers receive in order to work on complex

technical issues has a low degree of domain-specificity in this context. As an example, a expert in stealth technology, which in itself is unlikely to have applications in non-defence contexts, is almost certain to have a skill set based on either radar technology or materials science.

Similarly, and perhaps surprisingly, we find no evidence of a negative relationship between product- or service dimensions in business functions and DUT2 from defence to non-defence. This may highlight further that the main barrier to DUT2 is located in the managerial domain, but the possibility of perceptual bias of respondents cannot be excluded. Unfortunately, particularly as this result does not seem to align with interviewee statements, our results regarding the effect (or the lack of an effect) of such adaptations are inconclusive.

Overall, we can argue that these results indicate that the strength of the firm's identity can affect the likelihood and success of technology transfer. It therefore also affects the firm's ability to leverage its capabilities in markets which are considered to be inconsistent with the firm's super-ordinate social identity (Kane, 2010), i.e. outside the firm's identity domain (Livengood & Reger, 2010). The defence sector serves as a critical case in terms of sector-specific identity, as it is still an idiosyncratic environment characterised by strong institutional forces and rigorous requirements for conformity to regulations and norms. The adaptation to this environment, in cognitive and behavioural terms, has been shown here to negatively affect the transfer of technology and the redeployment of capabilities outside of this familiar environment.

6.1.2 Non-defence to defence technology transfer

The positive relationship between technological excellence and DUT2 from non-defence to defence applications indicates that firms with a strong focus on technology have been incentivised to transfer technology into the defence sector. This aligns well with government aims to procure more technology from non-defence sources (e.g. SDSR (Great Britain. HM Government, 2010)) as well as statements from many of the experts interviewed in this study. It would seem that there is scope for this transfer of technology, as many non-defence firms are technologically as advanced – or in fact more advanced in many fields which are of interest to defence procurement agencies. Such firms can then generate revenues by meeting this demand. The following quote from an industry expert emphasises this point:

> *"The main driver is from commercial to defence, as commercial solutions are well in advance of military solutions in many areas of surveillance, communications and user interfaces (software)."*

This underpins the significance of the firm's technological excellence on DUT2, as defence agencies will be in the market for advanced, "envelope-pushing" solutions to their often unique and complex problems. If superior technology is available outside the defence sector, and this technology fulfils a demand, it is likely that the transfer of such a technology will be supported. The alternative of developing such technologies "in-house", and not leveraging existing capabilities from other sources is likely to carry with it considerable costs, which constitute a growing problem in the current and recent defence sector procurement landscape. The following quote of a senior defence firm manager and academic underscores this effect:

> *"Accordingly, we find it relatively easy to present these benefits and, with the exception of some programmes that are not realistic, sell the cost-benefit analysis of exploiting such technology."*

In order to gain legitimacy in such a context, the transfer object must be technologically rare and valuable, in that it must be superior to existing defence sector solutions. As this thesis has focused on high technologies as opposed to commodities or generic products, this point underlies the effect of technological excellence. Although a pure technology orientation within defence firms can lead to the development of technologies which may not exist outside the sector, in order to gain legitimacy in defence, the majority of suppliers consciously communicate this commitment to the delivery of excellence in their products, services and activities. The following examples of statements from defence contractor websites fall in line with this:

> Rolls Royce (n.d.):
> *"Trusted to deliver excellence"*
>
> Babcock (n.d.):
> *"For over a century, Babcock has been a name synonymous with ultra-reliable engineering excellence"*
>
> Finmeccanica UK (2012, p.1) :
> *"Solutions through technology excellence – Proven performance. Worldwide"*

These three firms often operate as prime contractors and as such are likely to act as gatekeepers to the wider supply chain. As such they are likely to be heavily exposed to – and affected by – the isomorphic pressures of the UK MOD. Many lower-tier suppliers will also communicate such a commitment to excellence to varying degrees, but in order to enter such defence supply chains, this commitment to be superior in a given field is likely to improve the likelihood of a firm having something to offer which can be potentially valuable, and for such a transfer object to be accepted.

It is interesting that defence sector-specific identity does not have a significant effect on the likelihood of DUT2 from non-defence to defence applications. This result seems to refute the concept

of a “wall of separation” between defence and non-defence industries, based on cognitive and cultural effects. It would seem, at least in the UK context, that this identity-effect does not pose a significant barrier to DUT2 in this direction, at least not as a direct effect.

However, there is a significant interaction effect between defence sector-specific identity strength and the positive effect of technological excellence on the likelihood of DUT2 from non-defence to defence applications. This interaction, which weakens the positive effect of technological excellence, indicates that a strong defence sector-specific identity can inhibit the transfer of technology if there are existing prerequisites for such a transfer – in this case strong technological orientation. This can be seen as evidence that although there is statistically no direct effect, a strong identity can constitute a barrier, however, we propose this barrier is less of a “wall of separation” and more of a filter, or refractive medium. Given a potential candidate technology to transfer, identity can inhibit this transfer, as the concept captures cognitive rigidity of top level managers. [i.e. they may not see the applicability of the tech in the defence setting, or do not look for tech solutions in non-traditional fields].

Human asset specificity does not significantly affect the likelihood of DUT2 from non-defence to defence applications. This would seem to support the statements made by several experts consulted in this study that defence sector-specific skill specificity is not necessarily a barrier to DUT2. In fact, one interviewee asserted that it is likely that jobs cut by defence firms will be absorbed by the civilian sector. It would seem that technical knowledge embedded in employees poses no significant barrier to DUT2. This is made very clear by the following quote from another senior manager:

> *“Technology [transfer] = jobs [transfer], and the rest is academic”*

Therefore it would seem that technical skills do not pose a significant barrier, and that bottlenecks are more likely to appear in the areas of market knowledge and managerial factors.

It is important to note that we find no evidence for an effect of the adaptation of either the product- or service dimensions, captured in business function adaptation, on DUT2. It is very likely that there is an underlying influence here that we were not able to detect. A more granular analysis may be required to capture the precise locations of rigidities within the DUT2 context.

6.2 The effect of dependence on defence revenues on firms' intention to strategically refocus away from defence

We see that a strong emphasis on technology and technological excellence is driving firms to grow their non-defence businesses. These firms are likely to seek new opportunities in non-defence markets in the future. Their belief in the value of their technological resources therefore underlies the perceived opportunity to create value in new non-defence markets, or to grow their activities in existing non-defence markets.

However, we can see that a strong defence sector-specific identity moderates this effect, in that a strong identity weakens the positive effect. Again, this provides evidence for the hypothesised filter- or refraction effect related to a strong organisational identity. Although this effect may be driven by path dependency relating to a defence-centric strategic orientation, it is likely that this is also underpinned by cognitive rigidity of top level managers.

Regarding the effect of defence sales on the keenness of firms to diversify away from defence to non-defence activities, it is noteworthy that dependence on MOD revenues seems to be deterring firms from continuing to strategically focus on defence. As the same is not true of dependence on defence revenues in general, it can be deduced that firms in the defence industry are being incentivised to diversify away from their traditional core business: sales of defence equipment to "traditional" home markets. This diversification can take the form of geographic diversification, which can be seen in the growth of defence firms to non-traditional markets, such as Brazil, Turkey, and several states in SE Asia, but also in product diversification outside of defence. A firm heavily dependent on MOD (and therefore less exposed to international revenues) is therefore highly likely to be driven to seek opportunities in DUT2 projects. However, they are also likely to be investigating the possibilities of geographic diversification. This is challenging, due to many political factors, however can be seen in the development of many defence firms over the last decades, whereby more or less all large organisations have significantly "hedged their bets" geographically.

It is imperative to consider the timing of the study regarding this relationship. Recent government White Papers and other political narratives seem to be sending a strong signal that likely constitutes a large proportion of the effect measured here.

7 Implications

7.1 Theoretical Implications

This project has contributed to management theory in several ways. We present a study of the antecedents of technology transfer in the idiosyncratic defence sector. Such studies have been rare, and we see that a strong technology orientation can increase the likelihood of successful technology transfer. This in itself is not surprising; however, we find evidence that organisational identity affects the likelihood and success of technology transfer, by moderating this effect. The analysis of this phenomenon specifically in the defence sector has allowed us to identify this relationship, as the defence sector can be seen as a critical case regarding strong organisational identities.

This is a twofold contribution, as we have presented evidence that identity affects technology transfer into the defence sector and out of it. The effect of DUT2 from non-defence is affected by identity acting as a filter, or refractive medium, i.e. identity is a component of technological capabilities, and can in fact be seen as a dimension of these capabilities. Technological capabilities developed specifically in the defence sector can be seen to have this attribute, or "flavour", and this may distinguish them from comparable capabilities developed in other sectors, but based in similar technological fields. In essence, a defence sector capability in radar, or human interfaces, although developed involving human assets which may be transferrable to similar non-defence applications, potentially also using similar or identical capital assets etc, can be qualitatively different from such a capability developed in non-defence contexts. This is due to a variation on the identity dimension of the capability. This can then hinder transfer of this capability to non-defence applications, despite the innate "transferability" of staff and potentially of equipment. This adds a new dimension to the concept of "turning swords into ploughshares", but has management research consequences which reach into other sectors with specific identity domains.

We also present evidence that asset specificity as a barrier to technology transfer, and as a factor inhibiting resource fungibility, cannot be seen in isolation of cognitive rigidity of organisational members. Organisational social identity can act to strengthen asset specificity, but can act as an emergent phenomenon. Therefore, this poses challenges to the measurement of asset specificity, as this emergent effect may not be identifiable at the same unit of analysis as the assets themselves, i.e. employees with specialised knowledge are embedded in networks of people, and routines and physical resources are embedded in the organisation – and the social identity of the organisation can only be appropriately viewed at the level of the organisation, as it is a property of the social group, and may not be measurable from the observation of individual components of the group. It does

however have effects on the fungibility of these resources in the context of the individual organisation.

The other strand of this contribution to management research relates to a firm's willingness and ability to adopt technologies within specific identity domains. As the defence sector constitutes a strong and well defined identity domain, this identity effect weakens the positive relationship of technological excellence on the transfer of technology to such defence applications. Essentially, similarly to the "not invented here" phenomenon, certain technologies with specific "heritage" may be seen as inappropriate, despite the potential for these to solve challenging defence problems. This is another side to the fungibility argument, as managerial cognitive schemas and mental models may preclude the potential for technology to be adapted and transferred. This is likely driven by the strong institutional forces in the sector. And this phenomenon is present in a sector which is subject to distinct government pressures to increase the adoption of non-defence originating technologies wherever this may be feasible.

This again can be expanded to other sectors with strong identity effects. It is also feasible that this affects not only the adoption of technologies, but also of best practices, non-obligatory standards, external consultancy, etc. Perhaps this would even expand to the adoption of employment of staff with specific personality traits, or certain brands of equipment, for instance the firm's decision to use only a particular brand of personal computer. Therefore, we can expand the underlying questions relating to organisational identity, i.e. "who we are as an organisation" to include such items as "how we do things as an organisation".

Regarding the defence sector-specific literature, this project contributes to the conceptualisation of the "wall of separation". The existence of this phenomenon has been a subject of intense debate, and our results contribute by adding the qualitative dimension of the "wall" actually functioning more as a refractive medium or filter. It would seem to exist, but is not impermeable, instead it creates additional energy requirements to overcome it, and potentially the need to plan in detail the trajectory of the transfer object to achieve the intended goals of transfer.

7.2 Practical Implications

7.2.1 Firms involved in the defence industry

Our results indicate that firms involved in the defence industry must be aware of the effects of exposure to the strong institutional forces within the sector. Although it is clear that adaptation to the requirements, regulative and normative, is necessary to compete and sell to defence agencies, managers of such firms must be mindful of the wider ranging effects of such adaptation and focus. There will also be cognitive effects, stemming from involvement in the defence industry, combined with the strong technical focus which is often associated with engineering-led firms.

The negative interaction effect between defence sector-specific identity and technology orientation in DUT2 from defence to non-defence shows that firms developing technologies and applying them to defence solutions may be beset by the effects of path dependency, and cognitive rigidity. It is likely that often, such firms may benefit from scanning for potential applications for their technologies which they may not have imagined previously. To this end they may have to acquire capabilities in marketing in non-defence markets, as well as market knowledge which may be lacking. This is however of course not a panacea solution, as many defence firms have attempted this through technology brokering, joint ventures, licensing and many other technology transfer mechanisms. However, this study provides empirical evidence to underline the existence of this identity effect, and the more precisely define its nature.

We also provide evidence for a negative and significant interaction effect of defence sector-specific identity on the positive main effect of technological excellence, in the case of DUT2 from non-defence to defence. This result, combined with the above result, adds depth to the phenomenon. Not only does it reduce the ability to explore the external environment for potential new markets, it also inhibits a firm's ability to identify and leverage potential non-defence technologies, which may provide lucrative opportunities in defence. In order to transfer technology into defence, at least in the high-tech context, it is necessary to have some technological advantage over solutions already present in defence. If this is the case, it is necessary to be aware of the effects that identity strength can have. Similarly to the "not invented here" concept, it would seem that some individuals or entities in the defence sector are less able to identify and positively evaluate the potential for the adaption of technologies originating in non-defence sectors.

Schemes such as the Centre for Defence Enterprise (CDE) have of course improved this, as has the general shift in defence procurement to communications, surveillance, and other electronics-based

technologies. In an interview a manager of a small defence contractor that also engages in commercial markets supported this by stating that:

> *"the CDE is an excellent scheme for MOD to fund prototype developments, engage with the wider industry and has allowed our organisation to develop IP and products for our organisation ... [that…] a 3-person company cannot afford to do […] internally."*

Recent MOD publications such as the SDSR (Great Britain. HM Government, 2010) and the Currie report (Currie, 2011) have also outlined the intent to procure more from "non-traditional" sources and to acquire commercial off-the-shelf (COTS) technologies and products wherever possible. But there is likely to be an inertia effect in the realisation of these aims. As many behaviours and cognitive schemas are institutionalised in the defence sector, the attempt to transfer technology into defence is still likely to be met with challenges based on a lack of communication, understanding and experience.

7.2.2 Ministry of Defence and Wider Government

Our research shows that MOD procurement practices and the wider institutional effects to which defence contractors are subjected may drive a sector-specific identity in such firms and subsequently constitute a negative effect on the likelihood and success of technology transfer into – and out of the defence sector.

We have presented evidence that this effect takes the form of an interaction, whereby potentially successful candidate technologies may form the basis of a successful transfer of technology, but that this identity effect inhibits such transfers. This may lead to two overarching effects which may reduce positive outcomes for the MOD and the UK Government as a whole: 1) Reducing the scope for access to technologies originating in non-defence sectors; and 2) reducing the return on investment for defence technologies which may have been applicable to non-defence sectors (including the indirect effects of the diffusion of technological innovation throughout the economy).

Although it is naturally necessary for governments and defence agencies to regulate the defence industry, and to seek value for tax-payers money, there must be an awareness of the effects of the regulative, normative and cultural-cognitive institutional characteristics. The UK has a relatively open and competitive defence procurement landscape compared to many other countries, due to the relatively low regulation concerning foreign suppliers and initiatives such as the Centre for Defence Enterprise which aims to engage "non-traditional" suppliers; however, defence will always be an idiosyncratic, complex landscape.

Therefore, in order to maximise the rate of defence sector adoption of technologies developed outside of defence, it is likely to be necessary to reduce the cognitive and regulative barriers which face non-traditional suppliers. In fact, often the administrative burden can pose a significant challenge, as stated by a senior defence firm manager:

> *"The level of paperwork and administration on military programmes is also stifling at times. Some defence technology has moved in the other direction, but the costs associated with small production runs and the specific nature of the product has caused issues in obtaining market acceptance of the technology".*

This underlines another significant barrier to DUT2, which also stems from MOD requirements. Small production runs do not allow firms to spread their overheads over large production volumes, and often a great deal of R&D spending is spent on meeting high customisation requirements laid out by defence agencies. This increases the difficulty of taking on military work.

This can also have a negative effect on defence to non-defence DUT2, as firms engaged in military projects may in fact have developed novel, innovative technologies, but may have also spend significant amounts on R&D work aimed at meeting MOD customisation and specialisation requirements which may be redundant or in fact irrelevant in non-defence contexts.

These points serve to underline that the already well-known phenomenon of "over-specification" can still pose a significant barrier to firms wishing to transfer technology into and out of defence.

The strategic reorientation model has shown that firms heavily dependent on MOD revenues are likely to intend to refocus away from defence activities in the future. The implications of this are potentially far reaching. The UK Government and MOD have often stated their intention to retain on-shore capabilities in critical defence industries due to national security concerns (Great Britain. HM Government, 2010). However the shift away from a defence focus for these firms could be construed as being caused by a strategic devaluation of domestic defence business going forward. This effect should be closely monitored in the future.

In addition to this, as this study shows that there is growing evidence that the flow of technology into defence is of greater magnitude that the flow of technology out of defence, the future of specialised defence firms is potentially turbulent. Although the largest global defence firms represent some of the largest firms on the planet, much of the technology deployed by armed forces can be traced to non-defence origins. This is one symptom of a wider change in the relationship between the military and wider society. Whereas the idea of an insular defence industry protected by and funded by government was certainly the case many decades ago, this privileged position has been degrading.

Large defence manufacturers are now privately owned, profit-maximising entities, and not under direct government control. These points raise significant questions regarding the control of strategically critical but also potentially dangerous technologies. Although governments do heavily regulate defence exports, many actors in the industry operate from several “home” markets, and procure components from a range of suppliers that are also globally dispersed. This level of complexity and distributed control must raise questions regarding transparency and the implications of domestic level regulation and legislation.

Another point, which we believe is relevant, pertains to the level of defence spending itself. Throughout the study we have assumed that defence spending occurs, and sought to explore and analyse the effects of this spending. However, if it is assumed that the technology requirements of defence and non-defence customers are more similar now than several decades ago, the question must be posed: Is the allocation – particularly of R&D funding – effective given that there are possibilities of duplication. Assuming a growing magnitude of technology transfer into defence, it can be argued that non-defence commercial entities may be equally, if not more capable of delivering the capabilities defence agencies require. Perhaps more communication, collaboration and cooperation in all stages of the R&D process should be considered to assure efficient allocation of resources.

In order to gain from the non-defence technological base in the UK, MOD not only has to the practice of “smart acquisition” and behaving as a “smart customer”, but to employ effective, contemporary management principles in order to co-evolve with the wider industry. We hope that by carrying out this project based on contemporary management research methods and theory, a debate can be stimulated which can result in closer relations between MOD and the management community. Significant cooperation between business schools and other academic institutions with a focus on management has been fruitful in sectors such as healthcare, and it would be beneficial to expand this government-academic relationship in the defence sector context. This study has shown that the defence sector is a prime example of the management research concept of organisational identity, and brings to bear the findings from the literature in this field. As it would be beneficial for MOD to make use of this resource, cooperation with the MOD is likely to be the foundation of future research output into this and other related phenomenon. We believe this is an opportunity which should be pursued.

7.2.3 The armed forces

There are also significant implications from this work for the UK armed forces. In times of significant budgetary pressures, it is imperative that MOD procurement strategy achieves value for money. The acquisition of technologies from non-defence sources may, if they are effective, contribute to this. Initiatives such as CDE demonstrate that the MOD is aware of this opportunity and of the challenges associated. However, doing business with commercial firms may bring with it challenges which MOD is not accustomed to, as we have shown that defence contractors, particularly prime contractors, are heavily affected by isomorphic pressures resulting from the institutional forces present in the sector. Firms with less experience in selling to MOD may be disincentivised to become involved due to detailed specifications, complex regulations and strong cultural differences.

It is important to note at this point that the UK defence procurement landscape is relatively competitive and already has relatively strong ties to wider industry, compared to many other comparable nations. This bodes well for the future exploitation of technological innovation and cooperation between defence oriented- and wider research programmes, as well as firms, academic institutions and other stakeholders in general. In fact, there is strong evidence that technology developed in non-defence contexts is percolating into the defence sector.

However, the diffusion of technologies into defence must be seen as an alternative to in-house development. It has been shown that defence R&D spending is correlated with military capability, with a lag of roughly 10 years. The move to source more and more technology from non-defence sources, and opt for COTS solutions where feasible complicates this picture, which is already affected by decreasing defence expenditure. As technological advantage can be seen as a force multiplier, enhancing or maintaining military capability going forward, it is necessary to be aware of the implications of sourcing more and more technology from open markets. Without the radical innovation which has at times characterised the defence sector, the armed forces may have to re-evaluate what position, and which aims, are feasible for the UK in the future.

As this study indicated that there may be a significant shift away from MOD contracting due to perceived decline in the market, the UK armed forces must realise that the DIB may become less focused on delivering to the needs of the UK military. This is likely to increase the pressures for the UK to procure equipment from overseas, which may jeopardise onshore capabilities. It is already apparent that the RAF's next generation of combat aircraft will be procured from the USA, in the form of the JSF programme. Although BAE Systems is involved in the programme, the loss of a UK onshore capability in airframe development is likely to reduce the RAF's ability to influence and

specify the nature of the equipment it procures. There are also many further strategic considerations of losing such onshore capabilities.

8 Limitations

A primary limitation of this study was the restriction to a small sample size, confounded by the fact that it was challenging to attain a high response rate for the survey. We take care to indicate that this affects the degree to which the quantitative results can be interpreted, and conclusions made. We sought to compensate for this by employing an iterative approach throughout, combining the quantitative methods with exploratory and confirmatory interviews with a range of experts in industry, academia and other defence sector stakeholders. However, a large sample size would have been beneficial in terms of statistical results, and perhaps future studies could expand including a cross-country analysis, and/or with more formal and persuasive political or industrial support and coordination.

Additionally, as we used quantitative methods and a broadly implemented survey to investigate highly complex organisational phenomena, we may have missed certain detailed conclusions which would have been possible with an approach enabling a more granular view. We compensated for this again by supporting the study with a significant amount of expert interviews, however, future studies may add to our contributions by e.g. conducting more in-depth case studies to map out the complexities of the DUT2 phenomenon qualitatively, particularly with the view to capture changes over time, as we have shown that the sector is in a transition state.

In line with the above two points, it would be very beneficial to collect quantitative data over time to generate panel data. Not only would this capture changes over time, but also allow more robust conclusions to be made regarding temporal causality. This study was limited to a cross-sectional approach.

Another limiting factor was our design choice to target top managers in defence firms. Future research, particularly the aforementioned in-depth qualitative approaches, could aim to distinguish between identity effects at different levels of the target firms. As we discuss that organisational identity can be an emergent property of a system, such a project could add significant value to mapping out the percolation of identity effects throughout an organisation, and also to capture the effects of the plethora of inter-organisational links between organisations, which do not only occur at management level.

9 Conclusion

This study was conducted to investigate which firm-level factors influence the likelihood and success of DUT2. We have presented evidence that the phenomenon is primarily driven by the presence of a strong technology orientation, or the commitment to technological excellence at the firm level. Therefore, technology transfer is more likely if a technological advantage can be leveraged for competitive advantage in the target market. We have also shown that the firm's sector-specific identity inhibits this effect. This relationship, and its nature as an interaction effect, contributes both the defence sector-specific literature and the management research literature. We provide empirical evidence that a firm's identity can affect its ability to seek new opportunities in non-traditional markets, and to transfer technology into domains with strong sector-specific identities.

We find no evidence that human asset specificity or business function specificity acts as an inhibitor in this context. We do however suggest that these factors should be considered in more detail in future studies, as the quantitative research techniques used in this study may not capture the granularity and complexity of such adaptations within the complex environment of individual firms operating in this complex landscape. However, we can conclude that the asset specificity and capabilities must be seen in the context of the emergent property of organisational identity.

Evidence is also presented which would indicate that recent developments in the UK defence landscape are driving firms to diversify to non-defence activities and weaken their focus on the domestic UK defence market. This is likely due to strong signalling effects generated by narratives communicated by the current government. This is in line with a long-term reorientation of the UK defence market away from its traditional, classic isolated and heavily government-controlled roots, to a private sector, globally diversified industrial base of technologically sophisticated, innovative defence contractors, whose complex relationship with government and MOD is changing.

The future of the UK defence sector is likely to be turbulent; however, government initiatives to improve the engagement with "non-traditional" suppliers, opening up lucrative defence supply chains, and coordinating research and development activities may allow the innovations synonymous with the defence industry to continue to benefit the wider UK economy. However, as this sector is idiosyncratic and still characterised by strong institutional forces and a centralised buyer who also acts as a regulator, it will remain to be a unique and complex landscape. The results of this study indicate that the identity of firms and other stakeholders in the industry must be taken into account, if we wish to maximise the benefit which can be driven by highly skilled engineers, working for well organised firms, delivering technological innovation and excellence to an institution uniquely positioned to carry UK engineering innovation far into the 21st century.

References

Albert, S. & Whetten, D.A. (1985) *Organizational identity*. Research in organizational behaviour, Vol. 7. pp. 263-295.

Alic, J. A., Branscomb, L. M., Brooks, H., Carter, A. B., & Epstein, G. L. (1992) *Beyond Spinoff: Military and Commercial Strategies in a Changing World*. Cambridge, MA: Harvard Business School Press.

Anand, B.N. & Khanna, T. (2000) Do firms learn to create value? The case of alliances. *Strategic Management Journal*, 21(3), 295-315.

Anand, J. & Singh, H. (1997) Asset Redeployment, Acquisitions and Corporate Strategy in Declining Industries. *Strategic Management Journal*. Vol. 18, 99-118.

Ansoff, I. (1957) Strategies for Diversification, *Harvard Business Review*, Vol. 35 Issue 5,Sep-Oct 1957, 113-124.

Antill, P., Moore, D. & Neal, D. (2001) Supply Chain Management in SME's within the Defence/Aerospace Industry – a case of simplification or increased complexity? *Staff Publications – Cranfield Defence and Security, Shrivenham* Available at: http://dspace.lib.cranfield.ac.uk/handle/1826/7504 [Accessed: 10.07.2013]

Arundel, A. (2001) The relative effectiveness of patents and secrecy for appropriation. *Research Policy*, Vol. 30, 611–624.

Atlas, R. M. & Reppy, J. (2005) Globalizing biosecurity. *Biosecurity and Bioterrorism-Biodefense Strategy Practice and Science* 3(1): 51-60.

Autio, E. & Laamanen, T. (1995) Measurement and evaluation of technology transfer: review of technology transfer mechanisms and indicators. *International Journal of Technology Management,* Vol. 10, 643-664.

Avadikyan, A. & Cohendet, P. (2009) Between market forces and knowledge based motives: the governance of defence innovation in the UK. *Journal of Technology Transfer,* 34(5): 490-504.

Babcock (n.d.) About Us. [Online] Available from: http://www.babcockinternational.com/about-us/ [Accessed: 15.10.2012]

BAE Systems (n.d.) *Our Home Markets*. [Online]. Available from: http://www.baesystems.com/what-we-do-rzz/suppliers/our-home-markets [Accessed: 28.11.2012]

Barney, J. (1991) Firm Resources and Sustained Competitive Advantage. *Journal of Management*, 17(1), 99-120.

Barney, J., Bunderson, J., Foreman, P., Gustafson, L., Huff, A., Martins, L., Reger, R., Sarason, Y., & Stimpert, J. (1998) A strategy conversation on the topic of organization identity, in D Whetten, & P Godfrey (eds), *Identity in organizations: Building theory through conversations*, Foundations for organizational science: A SAGE publications series, SAGE Publications, Inc., Thousand Oaks, CA, pp. 99-169.

Bellais, R. & Guichard, R. (2006) Defence Innovation, technology transfers and Public Policy. *Defence and Peace Economics,* Vol. 17, 273-286.

Bennett, F. (2010) The Seven Deadly Risks of Defence Projects. *Security Challenges*, 6(3), 97-111.

Brown, A.D. & Starkey, K. (2000) Organizational Identity and Organizational Learning: A Psychodynamic Perspective, *Academy of Management Review*, 25(1), 102-120.

Campagnolo, D. & Camuffo, A. (2010) The Concept of Modularity in Management Studies: A Literature Review International Journal of Management Reviews

Cervino, M., Corradini, S. & Davolio, S. (2003) Is the 'Peaceful Use' of Outer Space Being Ruled out? *Space Policy,* Vol. 19, 231-237.

Cohen, W. & Levinthal, D. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, Vol. 35: 128-152.

Cohen, W.M., Nelson, R.R., & Walsh, J.P. (2000) Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent or not. NBER Working Paper n. 7552.

Corley, K.G., & Gioia, D.A. (2004) Identity Ambiguity and Change in the Wake of a Corporate Spin-Off. *Administrative Science Quarterly*, Vol. 49, 173-208.

Corley, K.G., Harquail, C.V., Pratt, M.G., Glynn, M., Fiol, C.M. & Hatch, M.J. (2006) Guiding Organizational Identity through Aged Adolescence. *Journal of Management Inquiry*, Vol. 15, 85- 99.

Cornelissen, J.P., Haslam, S.A. & Balmer, J.M.T. (2007) Social Identity, Organizational Identity and Corporate Identity: Towards an Integrated Understanding of Processes, Patternings and Products. *British Journal of Management*, Vol. 18 (special issue), 1-16.

Cowan, R. & Foray, D. (1995) Quandaries in the economics of dual technologies and spillovers from military to civilian research and development. *Research Policy,* Vol. 24, 851-868.

Cronberg, T. (1994) Civil Reconstruction of Military technology: The United States and Russia. *Journal of Peace Research,* Vol.31, 205-218.

Currie, D.A. – Lord of Marylebone (2011) Review of Single Source Pricing Regulations – An Independent Report into the single source pricing regulations used by the Ministry of Defence. [Online] London, Ministry of Defence, Gateway Reference: DGDC/2/2011. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/35913/review_single_source_pricing_regs.pdf [Last Access: 10.12.2012]

Cyert, R. M. & March, J.G. (1963/1992) *A Behavioural Theory of the Firm*. 2nd ed. Prentice Hall, Englewood Cliffs, NJ.

De Luca, L.M. & Atuahene-Gima, K. (2007) Market Knowledge Dimensions and Cross-Functional Collaboration: Examining the Different Routes to Product Innovation Performance. *Journal of Marketing*, Vol. 71, 95-112.

Demchak, C. (1992) Complexity, Rogue Outcomes and Weapon Systems *Organizational Challenges* Vol. 52 347-355.

DiMaggio, P.J. (1988) Interest and agency in institutional theory. In L. G. Zucker (Ed.), *Institutional Patterns and Organizations: Culture and Environment*: 3-22. Cambridge, MA: Ballinger

Dierickx, I. & Cool, K. (1989) Asset Stock Accumulation and Sustainability of Competitive Advantage. *Management Science*, 35 (12), 1504-1511.

Dowdall, P. (2004) Chain, networks and shifting paradigms: The UK defence industrial supply system. *Defence and Peace Economics,* 15(6), 535-550.

Dutton, J.E., & Dukerich, J.M. (1991) Keeping an Eye on the Mirror: Image and Identity in Organizational Adaptation. *Academy of Management Journal*, 34(3), 517-554.

Elder, B. (1992) A strategic approach to advanced technology trade with the soviet-union. *Comparative Strategy* 11(1), 65-81.

Eyre, D. P. & Suchman, M.C. (1992) Military Procurement as Rational Myth – Notes on the Social Construction of Weapons of Proliferation. *Sociological Forum,* Vol.7, 137-161.

Fiegenbaum, A. & Thomas, H. (1995) Strategic groups as reference groups: theory, modelling and empirical examination of industry and competitive strategy. *Strategic Management Journal*, 16(6),461-475.

Financial Times (08.08.2012) Mid-Sized defence groups – reality bites. *Financial Times* [Online] Available under: http://www.ft.com/cms/s/3/c2514d32-e152-11e1-839a-00144feab49a.html [Accessed: 10.08.2012]

Finmeccanica UK (2012) *Solutions through Technology Excellence*. [Online] Finmeccanica UK, London. Available under: http://www.finmeccanica.co.uk/pdf/Finmeccanica%20UK%20Brochure%202012.pdf [Accessed: 15.10.2012]

Fiol, C.M. (2002) Capitalizing on Paradox: The Role of Language in Transforming Organizational Identities. *Organization Science*, 13(6), 653-666.

Fiol, C.M., & Huff, A.S. (1992) Maps for Managers: Where are we? Where do we go from here? *Journal of Management Studies*, 29(3), 267-285.

Fuhrmann, M. (2008) Exporting mass destruction? The determinants of dual-use trade. *Journal of Peace Research,* 45(5), 633-652.

Galtung, J. (1979) *Development, environment, and technology: towards a technology for self-reliance*. United Nations Conference on Trade and Development, New York, United Nations.

Gansler, J. (1989) *Affording Defence* Cambridge, Ma.

Gatignon, H. & Xuereb, J-M. (1997) Strategic orientation of the firm and new product performance, *Journal of Marketing Research*, 34(1), Special Issue 'Innovation and New Products', 77-90.

Gertler, J. (2012) *F-35 Joint Strike Fighter (JSF) Program*. [Online] Congressional Research Service, CRS Report for Congress, Ref: 7-5700, RL 30563, 16.02.2012, available under: www.fas.org/sgp/crs/weapons/RL30563.pdf [Accessed: 28.11.2012]

Gioia, D.A., Schultz, M. & Corley, K.G. (2000) Organizational Identity, Image, and Adaptive Instability. *Academy of Management Review*, 25(1), 63-81.

Glynn, M.A. (2000) When cymbals become symbols: Conflict over organizational identity within a symphony orchestra. *Organization Science*, 11 (3), 285-298.

Glynn, M. A. & Abzug, R. (2002) Institutionalizing identity: Symbolic isomorphism and organizational names. *Academy of Management Journal*, Vol. 45, 267-280.

Grant, R. M. (1996) Prospering in dynamically-competitive environments: organisational capability as knowledge integration. *Organisation Science*, 7 (4), 375-87.

Gray, B. (2009) *A Review of Acquisition for the Secretary of State.* Independent report submitted to the Secretary of state for Defence. [Online] Available from: http://www.MOD.uk/NR/rdonlyres/78821960-14A0-429E-A90A-FA2A8C292C84/0/ReviewAcquisitionGrayreport.pdf [Last Access: 21.08.2012]

Great Britain. HM Government (2010) Securing Britain in an age of uncertainty: the Strategic Defence Security Review**.** London: The Stationery Office.

Great Britain. Ministry of Defence (2004). *The smart acquisition handbook: a guide to "faster, cheaper, better and more effectively integrated."* 5th Edition. London, Ministry of Defence.

Great Britain. Ministry of Defence (2005) *Defence Industrial Strategy 2005*. Defence White Paper CM 6697. London, Ministry of Defence.

Great Britain. Ministry of Defence (2006) *Defence Technology Strategy 2006*. Defence White Paper. London, Ministry of Defence.

Great Britain. Ministry of Defence (2009) *Defence Technology Plan 2009*. [Online] Available from: www.science.mod.uk/Strategy/dtplan/Default.aspx [Accessed: 08.02.2010]

Great Britain. Ministry of Defence (2009a) *Acquisition Operating Framework 2009 – Technology Readiness Levels.* [Online] London, Ministry of Defence. Available from: http://www.aof.mod.uk/aofcontent/tactical/techman/content/trl_whatarethey.htm [Accessed: 10.07.2011]

Great Britain. Ministry of Defence, Defence Analytical Services Agency (2011) *United Kingdom Defence Statistics, 2011*. [Online] London, The Stationary Office. Available from: http://www.dasa.MOD.uk/MODintranet/UKDS/UKDS2011/pdf/ukds.pdf [Accessed: 21.08.2012]

Great Britain. National Audit Office (2006) *Ministry of Defence - Using the contract to maximise the likelihood of successful project outcomes*. Reference HC 1047 2005-2006, London, The Stationary Office.

Gummett, P. (1990) Issues for STS Raised by Defence Science and Technology Policy. *Social Studies of Science,* 20(3), 541-558.

Hagedoorn, J. (1993) Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences *Strategic Management Journal* Vol. 14 371-385.

Hagedoorn, J.; Lorenz-Orlean, S.; van Kranenburg, H. (2008) Inter-firm technology transfer: partnership-embedded licensing or standard licensing agreements? *Industrial and Corporate Change*, 18(3), 529-550.

Hambrick, D.C. & Mason, P.A. (1984) Upper echelons: the organization as a reflection of its top managers. *Academy of Management Review*; 9(2), 193-206.

Hambrick, D. (1987) Top management teams: Key to strategic success. *California Management Review*, Vol. 30, 88-108.

Hartley, K., Hooper, N., Sweeney, M., Matthews, R., Braddon, D., Dowdall, P. & Bradley, J. (1997) *Armoured Fighting Vehicle Supply Chain Analysis, Study of the Value of the Defence Industry to the UK Economy*. Centre for Defence Economics, University of York, Vol. 1, unpublished.

Hartley, K. (2006) Defence Spending and its impact on the national economy: A review of the literature and research issues *University of York working papers*; [Online] Available under: http://www.york.ac.uk/depts/econ/documents/research/defence_spending.pdf [Accessed: 19.07.2010]

Hartley, K. (2007) The Arms Industry, Procurement and Industrial Policies. In: T. Sandler, & K. Hartley (Eds.), *Handbook of Defense Economics: Defense in a globalized world*, Vol. 2, Chapter 33. Oxford: North-Holland, pp. 1139-1174.

Hartley, K. (2011) Defence R&D Spending. *World Economics*, 12(1), 103-114.

Haslam, S. A., Postmes, T., & Ellemers, N. (2003). More than a metaphor: Organisational identity makes organisational life possible. *British Journal of Management*, 14, 357-369.

Heinrich, T. (2002) Cold War Armory: Military Contracting in Silicon Valley. *Enterprise and Society,* Vol. 3, 247-284.

Hirshleifer, D. & Teoh, S.H. (2003) Herd Behaviour and Cascading in Capital Markets: a Review and Synthesis. *European Financial Management*, 9(1), 25-66.

Hislop, D. (1997) Capabilities, Strategy and Environment: The Adaptation of the UK Military Aircraft Industry to the Post-Cold War Environment. *Technology Analysis & Strategic Management,* Vol.9, 3-18.

Hobday, M.; Davies, A. and Prencipe, A. (2005) Systems integration: a core capability of the modern corporation. *ICC*, Vol. 14 Issue 6, December 2005: 1109-1143.

Hurley, R. F. & Hult, T. (1998) Innovation, Market Orientation, and Organizational Learning: An Integration and Empirical Examination. *Journal of Marketing*, 62(3), 42-54.

Hutton, R. (1995) *Motivations for submarine acquisition in Asia*. Naval Postgraduate School, Monterey, California.

Insik, J., Jae, H.P. & Dongsheng, Z. (2006) Antecedents and consequences of the strategic orientations in new product development: The case of Chinese manufacturers. *Industrial Marketing Management*, 35(3), 348-358.

Janis, I. (1972) *Victims of groupthink*, Boston: Houghton-Mifflin.

Jeong, I.; Pae, J.H. & Zhou, D. (2006) Antecedents and consequences of the strategic orientations in development: The case of Chinese manufacturers. *Industrial Marketing Management*, Vol. 35, 348-358.

Kane, A.A. (2010) Unlocking knowledge transfer potential: Knowledge demonstrability and superordinate social identity. *Organization Science*, 21(3), 643-660.

Kelly, M. and Watkins, T. (1995) In from the Cold: Prospects for Conversion of the Defense Industrial Base. *Science*, Vol. 268 No.: 5210 525-532.

Kile, S.N., Fedchenko, V. & Kristensen, H.M. (2009) World Nuclear Forces. In: *SIPRI Yearbook 2009*, Chapter 8., Oxford, Oxford University Press, pp. 345-379.

Kim, J.-Y. J. & Miner, A. S. (2007) Vicarious learning from the failures and near-failures of others: Evidence from the U.S. commercial banking industry. *Academy of Management Journal*, 50(3), 687-714.

Kimberly, J. R. (1979) Issues in the creation of organizations: Initiation, innovation, and institutionalization. *Academy of Management Journal*, Vol.22, 437–457.

Kogut, B., & Zander, U. (1996) What firms do? Coordination, identity, and learning. *Organization Science,* 7(5), 502-518.

Krieger, D. (1981) *Disarmament and development. The Challenge of the International Control and Management of Dual-Purpose Technologies.* Rotterdam, Foundation Reshaping the International Order.

Kulve, H. & Smit, W. (2003) Civilian and military cooperation strategies in developing new technologies. *Research Policy,* Vol. 32, 955-970.

Lane, P. and Lubatkin, M. (1998) Relative Absorptive Capacity and interorganizational learning. *Strategic Management Journal* Vol. 19 Issue 5: 461-477.

Langlois, R. and Everitt, M. (1992) Complexity, genuine uncertainty, and the economics of organization *Human Systems Management* Vol. 11 67-75.

Leonard-Barton, D. (1992) Core Capabilities and core rigidities: A Paradox in managing new product development. *Strategic Management Journal,* Vol. 13, 111-125.

Leonard-Barton, D. (1992a) *Wellsprings of Knowledge: Building and sustaining the sources of innovation.* Harvard Business School Press Boston MA.

Livengood, R.S. & Reger, R.K. (2010) That's Our Turf!: Identity Domains and Competitive Dynamics. *Academy of Management Review*, Vol.35, 48-66.

Lowe, M. , George, G. & Alexy, O. (2012) Organizational identity and capability development in internationalization: transference, splicing and enhanced imitation in Tesco's US market entry *Journal of Economic Geography* Vol. 12: 1021-1054.

Malone, T.W., Yates, J. & Benjamin, R.I. (1987) Electronic Markets and Electronic Hierarchies: Effects of information technology on market structure and corporate strategies. *Communications of the ACM,* Vol. 30, 484-497.

Markusen, A. & Yudken, J. (1992) *Dismantling the Cold War Economy*. Basic Books, New York.

McLeish, C. & Nightingale, P. (2007) Biosecurity, bioterrorism and the governance of science: The increasing convergence of science and security policy. *Research Policy, Vol.* 36, 1635-1654.

Middleton, A., Browns, S., Hartley, K. & Reid, J. (2006) The Effect of defence R&D on Military Equipment Quality. *Defence and Peace Economics,* 17(2), 117-139.

Molas-Gallart, J. (1997) Which way to go? Defence technology and the diversity of "dual-use" technology transfer. *Research Policy, Vol.* 26, 367-385.

Molas-Gallart (1998) *Dual use technologies and the different transfer mechanisms.* The International School on Disarmament Research on Conflicts 19th Summer Course, Candriai.

Molas-Gallart, J. (1999) Measuring Defence R&D: A Note on Problems and Shortcomings *Scientometrics,* 45(1), 3-16.

Molas-Gallart, J. & Sinclair, T. (1999) From Technology Generation to Technology Transfer: The Concept and Reality of "Dual-Use Technology Centres". *Technovation,* Vol.19, 661-671.

Mowery, D.C. & Rosenberg, N. (1982) Technical change in the commercial aircraft industry, 1925-1975, In: Rosenberg, N. (Ed.), *Inside the Black Box: Technology and Economics*, Cambridge Univ. Press, Cambridge.

Mu, J. & Di Benedetto, A. (2011) *Strategic Orientations and New Product Commercialization: Mediator, Moderator, and Interplay.* [Online] Available under http://dx.doi.org/10.1111/j.1467-9310.2011.00650.x [Last Access 21.08.2012]

Murphy, L.M. & Edwards, P.L. (2003) *Bridging the valley of death – transitioning from public to private sector funding*, National Renewable Energy Laboratory, Golden, CO, USA.

Nadkarni, S. & Barr, P. (2008) Industry Context, Managerial Cognition, and Strategic Actions: An Integrated View. *Strategic Management Journal,* 29(13), 1395-1427.

Nadkarni, S., Herrmann, P. & Perez, P.D. (2011) Domestic mindsets and early international performance: The Moderating influence of international industry context. *Strategic Management Journal,* Vol. 32, 510-531.

Nag, R., Corley, K.G. & Gioia, D.A. (2007) The Intersection of Organizational Identity, Knowledge, and Practice: Attempting Strategic Change Via Knowledge Grafting. *Academy of Management Journal*, 50(4), 821-847.

Nelson, R.R. & Winter, S.G. (1982) *An evolutionary theory of economic change*. Belknap Press of Harvard University Press, Cambridge, Mass.

Nonaka, I. (1994) A dynamic theory of organizational knowledge creation. *Organization Science,* 5(1), 14-37.

Oliver, C. (1991) Strategic Responses to Institutional Processes. *Academy of Management Review*, 16(1), 145-179.

Parkhe, A. (1992) U.S. National Security Export Controls: Implications for Global Competitiveness of U.S. High-Tech Firms. *Strategic Management Journal,* Vol. 13, 47-66.

Penrose, E.T. (1959/1995). *The Theory of the Growth of the Firm*. 3rd ed. Oxford University Press, Oxford.

Petroni, G. & Verbano, C. (2000) The development of a technology transfer strategy in the aerospace industry: the case of the Italian Space Agency. *Technovation,* 20(7), 345-351.

Pinsonneault, A. & Kraemer, K. L. (1993) Survey research methodology in management information systems: An assessment. *Journal of Management Information Systems*, Vol.10, 75-105.

Ram, R. (2007) Defense expenditure and economic growth. In: T. Sandler, & K. Hartley (Eds.), *Handbook of Defense Economics: Defense in a globalized world*, Vol. 2. Oxford: North-Holland.

Reger, R.K., Gustafson, L.T., DeMarie, S.M. & Mullane, J.V. (1994) Reframing the Organization: Why Implementing Total Quality is Easier Said Than Done. *Academy of Management Review*, Vol. 19, 565-584.

Reppy, J. (1994) Technology Transfer: A Framework for Evaluating Policy. In: J. Reppy & J. Pilat (Eds.) *Defence Conversion and the Future of the National Nuclear Weapons Laboratories.* Proceedings of a Conference Held at Cornell University, Ithaca, NY, October 1993. Cornell University Peace Studies Program, Occasional Paper No. 18, Ithaca, pp 49-63.

ReutersVideo (2011) *Collaboration key to industry survival, says Lockheed Martin*. [Video] Available from: http://www.youtube.com/watch?v=bt8YFCveNpY&feature=related [Accessed 28.11.2012].

Rebolledo, C. & Nollet, J. (2011) Learning from suppliers in the aerospace *industry International Journal of Production Economics* Vol. 129, 328-337

Roberts, K. (1990) Some Characteristics of One Type of High Reliability Organization *Organizational Science* Vol. 1 No. 2 160-176.

Rogerson, W.P. (1994) Economic incentives and the defense procurement process. *The Journal of Economic Perspectives*, 8(4), 65.

Rolls-Royce (n.d.) Rolls-Royce – Our Brand. [Online] Available under: http://www.rolls-royce.com/about/brand/ [Accessed: 15.10.2012]

Round, W. (1993) *V-22: Dual Use Technology or Red Herring?* Executive Research Project at The Industrial College of the Armed Forces, Washington D.C. Available at: http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA276577 [Accessed: 12.07.2013]

Sandler, T. and Hartley, K. (Eds.) (2007) *Handbook of Defense Economics: Defense in a Globalized World. (Vol. 2)*. Oxford: North-Holland.

Sapienza, H.J., Parhankangas, A., & Autio, E. (2004) Knowledge relatedness and post-spin-off growth, *Journal of Business Venturing*, Vol. 19, 809-829.

Scott, W.R. (2001) *Institutions and Organizations*. 2nd ed., CA: Sage: Thousand Oaks.

Selznick, P. (1957) *Leadership in administration: A sociological interpretation*. Berkeley, University of California Press.

Shanteau, J. (1992) Competence in experts: The role of task characteristics. *Organizational Behavior & Human Decision Processes*, Vol. 53, 252-266.

Shotter, J; Jones, A.; Sakoui, A. (10.04.2012) Cobham in £270 m bid for Thrane & Thrane. *Financial Times* [Online] Available from: http://www.ft.com/cms/s/0/fd066daa-8d4b-11e1-9798-00144feab49a.html#ixzz2F45NVEWe [Accessed 12.04.2012]

Simon, H. (1969) *The Sciences of the Artificial.* Cambridge, MA.

Singh, K. (1997) The Impact of Technological Complexity and Interfirm Cooperation on Business Survival *Academy of Management Journal*, Vol. 40, No.2, 339-267

Slater, S., Olsen, E. Hult, G. (2006) The moderating influence on the strategy-formation capability-performance relationship. *Strategic Management Journal*, Vol. 27: 1221-1231.

Smith, D. & Tranfield, D. (2005) Talented Suppliers? Strategic change and innovation in the UK aerospace industry R&D Management, Vol. 35, 37-49

Song, X.M. & Parry, M.E. (1997) A cross-national comparative study of new product development processes: Japan and the United States, *Journal of Marketing*, Vol. 61, 1-18.

Spender, J.C. & Grant, R.M. (1996) Knowledge of the firm: Overview, *Strategic Management Journal*, Vol. 17, 5-9.

Stockholm International Peace Research Institute (2011). UK Military Expenditure 1988-2011. *SIPRI Military Expenditure Database*. [Online] Available under: Reference: http://milexdata.sipri.org [Accessed: 20.02.2012]

Stockholm International Peace Research Institute (2012). Trend Indicator Values of arms exports from the Top 50 largest exports 2011-2011. *SIPRI Armstrade Database*. [Online] Available under: Reference: http://armstrade.sipri.org/armstrade/page/toplist.php [Accessed: 28.11.2012]

Stowsky, J. (2004) Secrets to Shield or Share? New Dilemmas for Military R&D Policy in the Digital Age. *Research Policy,* Vol. 33, 257-269.

Subramani, M., & Venkatraman, N. (2003) Safeguarding Investments in Asymmetric Interorganizational Relationships: Theory and Evidence. *Academy of Management Journal*, 46(1), 46-62.

Tajfel, H., & Turner, J.C. (1979) An Integrative Theory of Intergroup Conflict, in: W.G. Austin and S. Worchel (Eds) *The Social Psychology of Intergroup Relations.* Monterey, CA: Brooks/Cole, pp. 33-47.

Teece, D. (1982) Towards an economic theory of the multiproduct firm. *Journal of Economic Behavior and Organization*, Vol. 3, 39-63.

Teece, D. (1986) Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, Vol. 15, 285-305.

Teece, D. (1998) Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intangible Assets. *California Management Review*, 40(3), 55–79.

Teece, D. (2007) Explicating Dynamic Capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, Vol. 28: 1319-1350.

Teece, D., Pisano, G. & Shuen, A. (1990) *Firm capabilities, resources and the concept of strategy, Consortium on Competitiveness and Cooperation.* Working Paper 90-9, University of California at Berkeley, Center for Research in Management, Berkeley, CA, 1990.

Teece, D., Pisano, G. & Shuen, A. (1997) Dynamic Capabilities and Strategic Management. S*trategic Management Journal,* 18(7), 509-533.

Thornton, P.H. & Ocasio, W. (1999) Institutional logics and the historical contingency of power in organizations: Executive succession in the higher education publishing industry, 1958-1990. *American Journal of Sociology,* 105(3), 801-843.

Tripsas, M. (2009) Technology, Identity, and Inertia Through the Lens of the Digital Photography Company. *Organization Science,* 20(2), 441-460.

Turner, J. C., Hogg, M. A., Oakes, P. J., Reicher, S., & Wetherell, M. S. (1987) *Rediscovering the social group: A self-categorisation theory.* Oxford: Basil Blackwell.

US Congress, Office of Technology Assessment, (1988) *Advanced Materials by Design*, OTA-E351, US Government Printing Office, Washington, DC.

U.S. Department of Defence (1992) Adjusting to the *Drawdown Report of the Defence Conversion Commission* Washington D.C.

Uzzi, B. (1997) Social structure and competition in interfirm networks: The paradox of embeddedness. *Administrative Science Quarterly*, Vol.42, 35-67.

von Hippel, E. (1994) "Sticky information" and the locus of problem solving: Implications for innovation. *Management Science,* 40(4), 429-439.

Welch, I. (2000) Herding Among Security Analysts. *Journal of Financial Economics,* 58(3), 369-396.

Williamson, O. E. (1996) *The Mechanisms of Governance*. Oxford University Press, New York.

Wind, J. & Mahajan, V. (1997) Issues and Opportunities in New Product Development: An Introduction to the Special Issue. *Journal of Marketing Research*, 34 (1), 1-12.

Wright, O. (14.08.2012) Philip Hammond: 'Games humanised the face of armed forces'. [Online] The Independent. Available under: http://www.independent.co.uk/news/people/profiles/philip-hammond-games-humanised-the-face-of-armed-forces-8038712.html [Accessed: 15.08.2012]

Yolles, M., Fink, G. & Dauber, D. (2011) Organisations as emergent normative personalities: part 1, the concepts. *Kybernetes*, Vol. 5/6, 635-669.

Zaheer, A. & Venkatraman, N. (1994) Determinants of Electronic Integration in the Insurance Industry: An Empirical Test. *Management Science*, 40(5), 549-566.

Zaheer, A. & Venkatraman, N. (1995) Relational governance as an interorganizational strategy: An empirical test of the role of trust in economic exchange. *Strategic Management* Journal, Vol.16, 373-392.

Zahra, S.A., Sapienza, H.J. & Davidsson, P. (2006) Entrepreneurship and Dynamic Capabilities: A Review, Model and Research Agenda. *Journal of Management Studies*, Vol. 43, 917-955.

Appendix

Appendix 1: Short form Questionnaire

Imperial College London

Dear Participant,

You are invited to complete the enclosed survey as part of a study into the effects of defence spending on the wider UK economy.

This study focuses specifically on the transfer of technology between defence and non-defence (incl. dual use) applications, in both directions (Dual Use Technology Transfer – DUT2). This study seeks to produce primary empirical evidence on this important phenomenon – how much of it is going on, when it is likely to occur, and what are its consequences.

This project is publicly funded (ESPRC), and the results will be made available after the project's completion.

All answers will remain strictly confidential. Results will be presented in aggregate format only. No references will be made to individual replies. Anonymity will be preserved.

This issue is of great importance to the UK defence community, and your responses will be greatly appreciated. For questions, please contact Liam Harris via liam.harris@imperial.ac.uk or +44 (0)79 [redacted]

C O M M E R C I A L I N C O N F I D E N C E

Section A

A1. Name of the organisation and, if applicable, your specific business unit:

A2. Please list the core technology- and service sectors, in which your business operates, for example Radar (maritime), Photo-optronics (all sectors), armour etc.:

A3. How would you estimate the following figures?

Please estimate the percentage…	**Percentage**
... of your organisation's revenue *currently* generated by defence sales	**%**
… of your organisation's revenue from defence *three years ago* (if known – please think about if this figure has changed over the last three years)	**%**
... of revenue currently generated by sales directly to UK MOD (if known)	**%**
... of your organisation's revenue generated by defence exports	**%**

A4. How do you view your organisation's primary position within the defence industry? **Please choose one of the following:**

- ☐ Prime Contractor
- ☐ Producer of Major Sub-Systems
- ☐ Lower Tier Supplier
- ☐ Other (please indicate)

A5. This survey is aimed at organisations with a focus on technology.
Does your organisation engage in Research, Development or Technology Demonstration (incl. software)?

Research	☐ Yes	☐ No
Development	☐ Yes	☐ No
Technology Demonstration	☐ Yes	☐ No

A6. How well do the following statements describe your organisation's identity?

To what extent do you agree with the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
Our management sees our organisation first and foremost as a defence supplier.	☐☐☐☐☐☐☐
Our important stakeholders (e.g. suppliers, customers, etc.) see us first and foremost as a defence supplier.	☐☐☐☐☐☐☐
Our employees identify strongly with the values of defence business.	☐☐☐☐☐☐☐
In our communication with important stakeholders, we consistently portray ourselves as a defence supplier.	☐☐☐☐☐☐☐
We see ourselves as supporting the national defence objectives rather than being purely profit-oriented.	☐☐☐☐☐☐☐
We employ ex-service personnel at senior management levels.	☐☐☐☐☐☐☐

A7. We are interested in specific functions carried out within your organisation:

To what extent are the following functions adapted specifically to meet *defence* customers' needs?	**N/A**	**Not at all←→Highly** **1 2 3 4 5 6 7**
Our research activities (e.g. selection of technological fields, fundamental research).	☐	☐☐☐☐☐☐☐
Our development activities (e.g. meeting defence customer specifications, product/service customisation, integration into defence systems/platforms).	☐	☐☐☐☐☐☐☐
Our product design activities.	☐	☐☐☐☐☐☐☐
Our manufacturing activities.	☐	☐☐☐☐☐☐☐
Our marketing/customer relationship management activities (e.g. tendering, contracting, identification of customers' needs).	☐	☐☐☐☐☐☐☐
Our distribution activities (i.e. we sell mainly to MOD/other defence agencies or within defence supply chains).	☐	☐☐☐☐☐☐☐
Our after-sales support activities (e.g. monitoring, maintenance)	☐	☐☐☐☐☐☐☐
Our other service activities (training, consulting, financing)	☐	☐☐☐☐☐☐☐

A8. We are interested in your organisation's attitudes to technological sophistication and design:

To what extent do you agree with the following statements?	**Disagree← →Agree** **1 2 3 4 5 6 7**
We build upon proven technological breakthroughs made by other organisations.	☐☐☐☐☐☐☐
We strive to achieve technological leadership in the markets in which we compete.	☐☐☐☐☐☐☐
We emphasise technological superiority to differentiate out new products.	☐☐☐☐☐☐☐
We aggressively adopt new technologies in the early phases of their introduction.	☐☐☐☐☐☐☐
We focus heavily on cost efficiency and strive to be a very "lean" organisation.	☐☐☐☐☐☐☐
We always prioritise quality over cost.	☐☐☐☐☐☐☐

A9. We are also interested in how you view the skills and knowledge of your organisation's employees:

To what extent do you agree to the following statements?	**Disagree←→Agree** **1 2 3 4 5 6 7**
Our organisation's market knowledge is focused specifically on the defence industry	☐☐☐☐☐☐☐
Our employees' market knowledge and skills are tailored to meet the specific conditions of our defence business.	☐☐☐☐☐☐☐
It would be very difficult for our employees to transfer market knowledge acquired in our organisation's defence business to applications outside the defence sector.	☐☐☐☐☐☐☐
Many of our employees can be considered specifically defence sector-specialists.	☐☐☐☐☐☐☐
We often hire new employees with a strong record in the defence sector.	☐☐☐☐☐☐☐
Our employees are intrinsically motivated to work on defence sector projects.	☐☐☐☐☐☐☐

A10. Please indicate whether or not your organisation attempts to interact with non-defence or dual use markets:

To what extent do you agree with the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
In the past we have put considerable effort into engaging with non-defence or dual use markets.	☐☐☐☐☐☐☐
We currently put considerable effort into engaging with non-defence or dual use markets.	☐☐☐☐☐☐☐
We plan to put considerable effort into engaging with non-defence or dual use markets in the future.	☐☐☐☐☐☐☐

A11. We are interested in the frequency and direction of knowledge and technology flows. Please indicate your assessment of the frequency of the transfer of the following items from non-defence or dual use to defence applications, and vice-versa:

How would you rate the frequency of the transfer of technology regarding…	**Defence to Non-defence/DU** **never ← → often** **1 2 3 4 5 6 7**	**Non-defence/DU to Defence** **Never ← → often** **1 2 3 4 5 6 7**
… basic research results	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… manufacturing techniques	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… materials	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… components	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… subsystems	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… platforms	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… complete systems	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐

A12. Has your organisation transferred technology from defence to non-defence or dual use applications or vice versa (as opposed to the parallel but separate development of technologies for non-defence or dual use and defence purposes)?

☐ We have never transferred technology from defence to non-defence applications, or vice versa

☐ We have only transferred technology from defence to non-defence applications

☐ We have only transferred technology from non-defence to defence applications

☐ We have transferred technology in both directions

Section B Additional Information

The following questions are voluntary, but we would appreciate any additional information, including any comments you may wish to add.

B1. In the light of this survey, we would be grateful if you could suggest any additional respondents who may be able to contribute. Please include their contact details.

B2. Please indicate your name, and position within your organisation. If you are willing to participate in further related research, please leave an email address. Also, if you have any specific queries regarding this research project, please give your contact details here, and include any queries in the comments section.

B3. We would appreciate any comments you may have which may help shed light on this topic

Thank you for completing the survey, your information is very valuable to this study and the results will be made available upon request.

For any other enquiries, please contact: Liam.Harris@imperial.ac.uk

Appendix 2: Long form Questionnaire

Imperial College London

Dear Participant,

You are invited to complete the enclosed survey as part of a study into the effects of defence spending on the wider UK economy. You have been selected as your organisation is a member of ADS.

This study focuses specifically on the transfer of technology between defence and non-defence (incl. dual use) applications, in both directions (Dual Use Technology Transfer – DUT2). This survey is designed to identify which factors influence the success of DUT2 at the organisation and the project level. We would like to gather information on your organisation, as well as a recent DUT2 project carried out by your organisation (if available).

This project is publicly funded (ESPRC), and the results will be made available after the project's completion.

All answers will remain strictly confidential. Results will be presented in aggregate format only. No references will be made to individual replies. Anonymity will be preserved.

This issue is of great importance to the UK defence community, and your responses will be greatly appreciated. For questions, please contact Liam Harris via liam.harris@imperial.ac.uk or +44 (0)79 [redacted]

C O M M E R C I A L I N C O N F I D E N C E

Section A

A1. Name of the organisation and, if applicable, your specific business unit:

A2. Please list the core technology- and service sectors, in which your business operates, for example Radar (maritime), Photo-optronics (all sectors), armour etc.:

A3. How would you estimate the following figures?

Please estimate the percentage…	**Percentage**
... of your organisation's revenue *currently* generated by defence sales	**%**
… of your organisation's revenue from defence *three years ago* (if known – please think about if this figure has changed over the last three years)	**%**
... of revenue currently generated by sales directly to UK MOD (if known)	**%**
... of your organisation's revenue generated by defence exports	**%**

A4. How do you view your organisation's primary position within the defence industry? **Please choose one of the following:**

☐ Prime Contractor

☐ Producer of Major Sub-Systems

☐ Lower Tier Supplier

☐ Other (please indicate)

A5. This survey is aimed at organisations with a focus on technology.
Does your organisation engage in Research, Development or Technology Demonstration (incl. software)?

Research	☐ Yes	☐ No
Development	☐ Yes	☐ No
Technology Demonstration	☐ Yes	☐ No

A6. How well do the following statements describe your organisation's identity?

To what extent do you agree with the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
Our management sees our organisation first and foremost as a defence supplier.	☐☐☐☐☐☐☐
Our important stakeholders (e.g. suppliers, customers, etc.) see us first and foremost as a defence supplier.	☐☐☐☐☐☐☐
Our employees identify strongly with the values of defence business.	☐☐☐☐☐☐☐
In our communication with important stakeholders, we consistently portray ourselves as a defence supplier.	☐☐☐☐☐☐☐
We see ourselves as supporting the national defence objectives rather than being purely profit-oriented.	☐☐☐☐☐☐☐
We employ ex-service personnel at senior management levels.	☐☐☐☐☐☐☐

A7. We are interested in specific functions carried out within your organisation:

To what extent are the following functions adapted specifically to meet *defence* customers' needs?	**N/A**	**Not at all←→Highly** **1 2 3 4 5 6 7**
Our research activities (e.g. selection of technological fields, fundamental research).	☐	☐☐☐☐☐☐☐
Our development activities (e.g. meeting defence customer specifications, product/service customisation, integration into defence systems/platforms).	☐	☐☐☐☐☐☐☐
Our product design activities.	☐	☐☐☐☐☐☐☐
Our manufacturing activities.	☐	☐☐☐☐☐☐☐
Our marketing/customer relationship management activities (e.g. tendering, contracting, identification of customers' needs).	☐	☐☐☐☐☐☐☐
Our distribution activities (i.e. we sell mainly to MOD/other defence agencies or within defence supply chains).	☐	☐☐☐☐☐☐☐
Our after-sales support activities (e.g. monitoring, maintenance)	☐	☐☐☐☐☐☐☐
Our other service activities (training, consulting, financing)	☐	☐☐☐☐☐☐☐

A8. We are interested in your organisation's approach to confidentiality:

To what extent do you agree with the following statements?	**Disagree←→Agree** **1 2 3 4 5 6 7**
Our research is mostly specific to the defence sector and of a sensitive nature.	☐☐☐☐☐☐☐
We are willing to make our research results available to other organisations and industries.	☐☐☐☐☐☐☐
Keeping our organisation's R&D knowledge from spreading to other organisations is important to our long-term success.	☐☐☐☐☐☐☐
We would adjust our approach to R&D in order to prevent potential competitors from benefitting from our work.	☐☐☐☐☐☐☐

A9. We are interested in your organisation's attitudes to technological sophistication and design:

To what extent do you agree with the following statements?	**Disagree←→Agree** **1 2 3 4 5 6 7**
We build upon proven technological breakthroughs made by other organisations.	☐☐☐☐☐☐☐
We strive to achieve technological leadership in the markets in which we compete.	☐☐☐☐☐☐☐
We emphasise technological superiority to differentiate out new products.	☐☐☐☐☐☐☐
We aggressively adopt new technologies in the early phases of their introduction.	☐☐☐☐☐☐☐
We invest significant effort in the aesthetic elements of design.	☐☐☐☐☐☐☐
We always prioritise functionality over style.	☐☐☐☐☐☐☐
Our new products are generally more visually appealing than those of our competitors.	☐☐☐☐☐☐☐
We focus heavily on cost efficiency and strive to be a very "lean" organisation.	☐☐☐☐☐☐☐
We always prioritise quality over cost.	☐☐☐☐☐☐☐

A10. We are also interested in how you view the skills and knowledge of your organisation's employees:

To what extent do you agree to the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
Our organisation's market knowledge is focussed specifically on the defence industry	☐☐☐☐☐☐☐
Our employees' market knowledge and skills are tailored to meet the specific conditions of our defence business.	☐☐☐☐☐☐☐
It would be very difficult for our employees to transfer market knowledge acquired in our organisation's defence business to applications outside the defence sector.	☐☐☐☐☐☐☐
Many of our employees can be considered specifically defence sector-specialists.	☐☐☐☐☐☐☐
We often hire new employees with a strong record in the defence sector.	☐☐☐☐☐☐☐
Our employees are intrinsically motivated to work on defence sector projects.	☐☐☐☐☐☐☐

A11. Please indicate whether or not your organisation attempts to interact with non-defence or dual use markets:

To what extent do you agree with the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
In the past we have put considerable effort into engaging with non-defence or dual use markets.	☐☐☐☐☐☐☐
We currently put considerable effort into engaging with non-defence or dual use markets.	☐☐☐☐☐☐☐
We plan to put considerable effort into engaging with non-defence or dual use markets in the future.	☐☐☐☐☐☐☐

A12. We are interested in the frequency and direction of knowledge and technology flows. Please indicate your assessment of the frequency of the transfer of the following items from non-defence or dual use to defence applications, and vice-versa:

How would you rate the frequency of the transfer of technology regarding…	**Defence to Non-defence/DU** **never ← → often** **1 2 3 4 5 6 7**	**Non-defence/DU to Defence** **Never ← → often** **1 2 3 4 5 6 7**
… basic research results	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… manufacturing techniques	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… materials	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… components	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… subsystems	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… platforms	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐
… complete systems	☐☐☐☐☐☐☐	☐☐☐☐☐☐☐

A13. Has your organisation transferred technology from defence to non-defence or dual use applications or vice versa (as opposed to the parallel but separate development of technologies for non-defence or dual use and defence purposes)?

☐ We have never transferred technology from defence to non-defence applications, or vice versa

☐ We have only transferred technology from defence to non-defence applications

☐ We have only transferred technology from non-defence to defence applications

☐ We have transferred technology in both directions

If you have answered 'No' to the previous question, you have completed the survey. Thank you very much for taking the time. However, we would value any additional comments you may have, which you can include at the end of the survey.

If you have answered 'Yes', please continue with Section B of the survey.

Section B DUAL-USE TECHNOLOGY TRANSFER (DUT2)

We would now like to enquire about a specific Technology Transfer project initiated by your organisation. Please provide as much information as you can within the bounds of confidentiality regarding your organisation's most recent technology transfer project and indicate if the transfer was from defence to non-defence or dual use or vice versa.

B1. Please indicate the name and the technology sector of the current/most recent DUT2 project that your organisation has been involved in. If a specific application was developed, please describe it:

B2. When did the project begin (MM/YY)? Project duration (Y+M):

B3. Please indicate the direction of technology transfer:

☐ Defence to Non-defence/DU ☐ Non-defence/DU to Defence

B4. Please indicate the mechanisms your organisation employed to transfer this technology:

Internally-led commercialisation (in-house project)	☐Yes	☐No
Technology licensing	☐Yes	☐No
Technology brokering	☐Yes	☐No
Formation of a spin-off company	☐Yes	☐No
Collaborative partnerships (e.g. Joint Venture)	☐Yes	☐No
Other (please specify):	☐Yes	☐No

B5. Was the DUT2 project launched into the target market? ☐Yes ☐No

B6. We are interested in the way this specific project is/has been affected by the regulatory environment:

Please indicate the level of challenge associated with…	**none← →severe** **1 2 3 4 5 6 7**
… granting of patents or other forms of intellectual property protection	☐☐☐☐☐☐☐
… management of Intellectual Property Rights (IPR)	☐☐☐☐☐☐☐
… International Traffic in Arms Regulations (ITAR) restrictions	☐☐☐☐☐☐☐
… Intra Community Transfer Directive or UK export controls	☐☐☐☐☐☐☐
… Offsets	☐☐☐☐☐☐☐
Other (please specify):	☐☐☐☐☐☐☐

B7. We are now interested in how mature the technology was at the point of transfer.

What Technology Readiness Level (TRL) would you attribute to the technology or product at the time of transfer?

TRL								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
☐	☐	☐	☐	☐	☐	☐	☐	☐

B8. We are interested in the required level of customisation relating to the DUT2 project:

To what extent do you agree to the following statements?	**Disagree ← → Agree** **1 2 3 4 5 6 7**
The product or technology transferred in/out required significant further work/customisation prior to launch in the market.	☐☐☐☐☐☐☐
The product or technology requirements/specifications for this market were substantially different from those of our pre-transfer market.	☐☐☐☐☐☐☐
This product or technology transferred in/out is used differently by non-defence applications, as opposed to defence applications, or vice versa.	☐☐☐☐☐☐☐
This product or technology transferred in/out was primarily "off-the-shelf".	☐☐☐☐☐☐☐
The existing product or technology has been significantly worked on to produce a marketable product or technology.	☐☐☐☐☐☐☐

B9. We are interested in the relationship between the DUT2 project and your organisation's other products and operations:

To what extent do you agree with the following statements? Related to our existing operations, the DUT2 project…	**Disagree ← → Agree** **1 2 3 4 5 6 7**
... is targeted at the same or very similar customers.	☐☐☐☐☐☐☐
... utilises existing distribution networks.	☐☐☐☐☐☐☐
... utilises the same or very similar manufacturing processes.	☐☐☐☐☐☐☐
... is similarly impacted by changes in the market place.	☐☐☐☐☐☐☐
... requires raw materials we also use elsewhere.	☐☐☐☐☐☐☐
... is associated with similar accounting systems and practices.	☐☐☐☐☐☐☐
... makes use of existing or highly similar management skills.	☐☐☐☐☐☐☐
... shares the same quality emphasis as our broader range.	☐☐☐☐☐☐☐

B10. Did the project involve any other organisations or business units? If so, please estimate the proportion of project activities within the project which were carried out by the other organisation(s) or business unit(s) or indicate if it is not applicable.

Low Proportion		**Level of involvement of others**					**Majority**
N/A	**1**	**2**	**3**	**4**	**5**	**6**	**7**
☐	☐	☐	☐	☐	☐	☐	☐

B11. Please briefly indicate the type(s) of external organisations involved in the DUT2 project (if applicable):

B12. Were any of the following funding arrangements involved in the project?

Government grants	☐Yes	☐No
EU grants	☐Yes	☐No
MOD R&D contracts	☐Yes	☐No
Other (please specify):	☐Yes	☐No

B13. We are interested in the way you view the performance of the DUT2 project either currently, or on completion / abandonment of the project:

How would you rate the performance of the DUT2 project in regards to the following aspects?	**Worse ← than expected → Better** **1 2 3 4 5 6 7**
The project has been completed within budget.	☐☐☐☐☐☐☐
The project has met the staffing objectives.	☐☐☐☐☐☐☐
The project has been completed on time.	☐☐☐☐☐☐☐
The project has met the quality objectives.	☐☐☐☐☐☐☐
The project has met the reliability objectives.	☐☐☐☐☐☐☐
The project has met the efficiency objectives.	☐☐☐☐☐☐☐
The project has met the user/client satisfaction objectives.	☐☐☐☐☐☐☐
The project has met the service objectives.	☐☐☐☐☐☐☐
The project has achieved the revenue stream objectives.	☐☐☐☐☐☐☐
The project has achieved the market share objectives.	☐☐☐☐☐☐☐
The project has achieved the profitability objectives.	☐☐☐☐☐☐☐
The project has achieved the objectives overall.	☐☐☐☐☐☐☐

B14. In the context of funding the project, to what extent was having funding partners important? Did the project involve funding from outside parties? (for example Government Grants, EU Grants, MOD R&D contracts, etc.) If so, which funding source(s) were involved?

B15. What revenue has the DUT2 project generated to this point? £

B16. What is the product's current market share? %

Section C Additional Information

The following questions are voluntary, but we would appreciate any additional information, including any comments you may wish to add.

B4. In the light of this survey, we would be grateful if you could suggest any additional respondents who may be able to contribute. Please include their contact details.

B5. Please indicate your name, and position within your organisation. If you are willing to participate in further related research, please leave an email address. Also, if you have any specific queries regarding this research project, please give your contact details here, and include any queries in the comments section.

B6. We would appreciate any comments you may have which may help shed light on this topic

Thank you for completing the survey, your information is very valuable to this study and the results will be made available upon request.

For any other enquiries, please contact: Liam.Harris@imperial.ac.uk