SATELLITES, ROCKETS AND SERVICES:
A PLACE FOR *SPACE* IN GEOGRAPHY?

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ABSTRACT

Despite the importance of satellite-enabled applications to society, geographical discussions of the *space* sector have been dominated by accounts of the geopolitics 'up there', without due consideration of the industry driving the use of *space* 'down here'. As a result, the geography of the *space* sector, and the interactions between the agents and institutions involved, have been overlooked in the academic literature. To address this 'silence', this thesis explores the competitiveness, organisation and governance of the UK *space* sector.

The primary method of data collection for this thesis was eighty semi-structured interviews with representatives from the UK *space* sector. The conceptual framework integrated economic and geopolitical concepts on competitiveness, organisation and governance.

Key findings of this thesis include: (i) orbital slots and frequency spectrum are competitive assets, which highlight the verticality of our economy; (ii) heritage is a source of competitiveness, which can cause technological lock-in; (iii) different segments within the UK *space* sector manage their own production projects, which are linked by buyer-supplier relationships (BSRs); (iv) BSRs are influenced by buyers, contracts, technology, time and geography; and (v) the governance of the UK *space* sector is multi-centric, with a dominance of regulatory forms.

This thesis is dedicated to my parents, Garry and Deborah Billing,

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CHAPTER 1

GEOGRAPHY AND OUTER *SPACE*

"*Space* is a means to various ends, and not an end in itself"

(Mazurelle *et al*., 2009:156).

On October 4th 1957, Sputnik was launched by the Soviet Union; it was the first artificial satellite[1] to be placed in outer-*space*[2]. This launch, by an R-7 intercontinental ballistic missile, was indicative of the nuclear warhead capabilities of the Soviets (MacDonald, 2008; Siddiqi, 2000; Launius, 2002). It marked the beginning of the *space* race, as *Space* exploration became another "arena for Cold War competition" (Spinardi, 2006:280). The subsequent milestones in this Cold War competition involved sending humans into orbit and the finale lay with the successful lunar landing by the U.S. Apollo 11 astronauts on July 16th 1969. Forty-seven years later, advanced satellite technologies (i.e. increased capacity and power) enable a range of economic, environmental, social and defence-related applications (Maral and Bousquet, 2011). The challenge presented by the 'new *space* race' is who can capitalise on these applications which have transformed life on Earth by producing the technologies required to deliver them. Satellite-enabled applications can be grouped into five broad categories: (i) communication; (ii) navigation; (iii) defence and security; (iv) weather forecasting and environmental monitoring; and (v) land stewardship. Different types of applications apply to different types of satellites. Examples of each

[1] A satellite is "any natural or artificial body moving around a celestial body [outer *space*] such as, planets and stars" (Agrawal, 2011:9). Man-made satellites are known as 'artificial satellites' to distinguish from natural satellites such as the moon. The 'satellites' referred to in this thesis are all artificial.

[2] To differentiate between *space* (meaning outer *space*) and the geographical space around us (the "primary analytic for contemporary human geography") (MacDonald, 2008:612), outer *space* is written in italics.

category are outlined below and the implications of the growing number of satellite-enabled applications are discussed.

Communication

Telecommunications satellites transmit signals from one point to another. This allows ships, planes and mobile Earth stations to communicate distress signals and data (Maral and Bousquet, 2011). It is also means that in areas where fibre optics and cables are unavailable, satellite broadband can ensure communication and connectivity via the internet. This presents opportunities for countries with low levels of economic development, as the internet provides access to training and educational opportunities, generating skills and encouraging aspirations across society. Additionally, telecommunications satellites help international business to overcome distance, as they enable the transfer of knowledge and information (for example, via video conferencing), without the need for face-to-face exchange (Hottes, 1993). Telecommunications satellites are also of "paramount importance" to the broadcasting of live events and news gathering from far flung places (Maral and Bousquet, 2011; Baimbridge *et al*., 1996).

Navigation

Global positioning satellites (GPS) provide "targets with known positions in *space* from which objects on Earth can triangulate their positions" (Johnson, 2007:177). There are two principal navigation systems: (i) the NAVSTAR GPS (US Department of Defence); and (ii) GLONASS (Russian) (Lechner and Baumman, 2000). Galileo, Europe's Global Satellite Navigation System, is also expected to be completed in 2020 (ESA, 2015). These global positioning systems enable anyone with a handheld receiver to determine their locations, which assists with travel (Scott, 1996). In addition, GPS has unlocked a whole series of applications. For example, field observations by farmers can be synchronised with the position of their fertilising trucks to vary the rate of "chemical prescription for each field" (SA, 2016; Lechner and Baumman, 2000). Additionally, manufacturers can track the location of their goods to provide a rolling inventory management (Varshney *et al.*, 2000).

Defence and Security

Defence satellites enable communication, surveillance, Earth observation and navigation for security purposes (Teodora and Bruston, 2009; Warf, 2007; Sloterdijk, 1998). For example, satellite cameras "capture images anywhere, anytime" irrespective of environmental and political obstacles on the ground (Adey *et al*., 2013). This allows military and intelligence organisations to track and monitor suspicious activity and secure perimeters. Additionally, satellite communications enable specialist overseas surgeons to watch a medical team operate in a conflict zone and provide necessary support. Consequently, *space* is the new "high ground" for defence and security (Johnson, 2007:141).

Weather forecasting and environmental monitoring

Meteorological satellites "generate data on cloud formation, tropical storms, hurricanes, likelihood of forest fires and temperature profiles" (Agrawal, 2011). This forecasting positively impacts on a range of businesses including: (i) distribution companies interested in potential weather disruption to traffic (Eneberg, 2016); (ii) supermarkets, on deciding whether to stock BBQ food (Metoffice, 2015); and (iii) fishing companies, on knowing when artic ice is expected to melt and fish are free to catch (ESA, 2015b). Meteorological satellites are also used to track extreme weather events (such as flooding), and to facilitate appropriate emergency relief. They can also monitor ocean temperature, the changing size of glaciers and long-term weather patterns (Kidd, 2010:3). These provide critical datasets for climate change research (BIS, 2011:119).

Land Stewardship

Earth observation satellites detect natural resources, including water, whilst monitoring erosion and contamination (of water and land) (ESA, 2016b). They also identify any leaks or breaks in large-scale infrastructure (such as oil pipelines) (UNOOSA, 2016). Earth observation satellites can also provide data on the use of a city by its inhabitants/visitors in order to help understand, analyse and plan future changes. For example, the speed, location and patterns of movement of commuters can be tracked to monitor the efficiency of public transport (TravelAI, 2016).

Implications of the Growing Number of Satellite-Enabled Applications

With the increasing number of satellite-enabled applications there has been "a marked trend towards greater dependence on *space*-based capabilities" by governments, the public and commercial users (Gov.uk, 2015). This growing dependence means that disruption to the production of these applications poses significant security, societal and economic risks. To help mitigate these risks it is important that we have a clear understanding of the competitiveness, organisation and governance of the firms involved. This insight will highlight how sustainable the firms are and their dependency on one another. It will also help guide policy makers on how best to support them. The firms include: (i) manufacturers of launch vehicles, ground systems and satellites; (ii) operators, who control the satellite when in orbit and sell communication bandwidth, position signals or observation data; and (iii) satellite application providers, who supply *space*-enabled services such as satellite television. These three groups of firms are referred to as 'sub-sectors' or 'segments' of the *space* sector (London Economics, 2015; Gov.UK, 2014). Launch providers also play a critical role in the global *space* sector. However, since the UK government pulled out of launch and manned *space* missions in 1970, there are currently no launch sites in the UK. Consequently, the term '*space* sector' and 'satellite industry' are often used interchangeably when referring to the UK, since satellites are at the centre of the UK's *space* activities.

Despite the strategic importance of satellite-enabled applications to the economy, environment and defence, there is limited geographical literature on *space*, which in any event ignores the 'grounded nature' of the *space* sector and how incorporated it is into national economies and life on Earth (Macdonald, 2008; Collis, 2009; Warf, 2006; Beery, 2012; Wang, 2009). As a result, the spatial configurations of satellite firms and the "interactions between the multifarious sets of actors, agents and institutions" involved is an "undeveloped avenue of inquiry" (Dicken, 2006:14; MacDonald, 2007:603). To address this 'silence' in the economic geography literature, this thesis explores the competitiveness, organisation and governance of the UK *space* sector (Dicken, 2006). There are economic and political aspects to this. Therefore, whilst economic geography will be the primary research lens, political geography will also inform the debate (particularly the governance of the industry). This engagement between the two sub-fields is important, since an entirely economic lens would be insufficient in reflecting the geopolitical influences which impact on the sector.

1.1 Genesis of the Research

The inspiration behind the research emerged from: (i) my curiosity of *space* from a young age; and (ii) the increased government support for the UK *space* industry in 2012. This section explains the impact of both factors and how they interrelate.

1.1.1 Why *Space*?

"*There are two things that get kids into science – dinosaurs and space*"
(David Willetts, Minster for Universities and Science, 2010)

Figure 1: My first trip to Kennedy *Space* Centre, Florida (Age 12).

Like most children, I grew up fascinated by *space*. This interest peaked during my first visit to Kennedy *Space* Centre in Florida at the age of twelve (Figure 1). However, ten years later *space* was not at the forefront of my mind, since I had pursued other academic interests. Nevertheless, a discussion with my University supervisor in 2012 about the UK Government's support for the *space* sector reignited my childhood curiosity. The Coalition Government had pledged a five-year investment of £1.2 billion in the European Space

Agency (ESA), in response to *space* having been identified as one of eight key sectors driving UK economic growth (in 2011) (IOD, 2012; BIS, 2014). I found this level of support surprising, considering that at the time I, like many others, associated *space* with NASA (U.S. National Aeronautics and Space Administration) and not UK applications. Through further research I found that the UK had a long history of activity in *space*. For example, the UK launched the first international satellite, Ariel-1, in 1962. Furthermore, in 2012/13 the UK *space* sector had a turnover of £11.3 billion, contributing £4.8 billion to national GDP (UK Space Agency, 2014). This direct contribution was in addition to the enhancement or facilitation of activities elsewhere in the UK economy and society, through the use of *space*-enabled applications.

The importance of *space* to the UK economy prompted my MSc study on the key sources of competitiveness for UK *space* manufacturers (Billing, 2013). This project was the "first detailed analysis of *space* manufacturing by Economic Geographers" and consisted of twenty-eight interviews with UK firms involved in the production of components which go into the Earth's orbit or beyond (Billing, 2013:61). The focus on the 'upstream' or *space* manufacturing sector was inspired by my interest on the uncertainty surrounding the sources of competitiveness for UK manufacturers, who are increasingly faced with price-based competition and other market disturbances (Simmie and Martin, 2008; Hill *et al*, 2008; Bryson and Taylor, 2010).

However, by ignoring the role of other agents in the industry (i.e. satellite operators and application providers) and the nature and extent of the manufacturers' relationships with those agents, it provided a limited understanding of firm-level competitiveness and of the complexity of the wider *space* industry. Additionally, the analysis found that satellite-enabled applications are by far the largest segment (78% of *space* sector turnover), with satellite operations second (12% of turnover) and *space* manufacturing third (8% of turnover) (London Economics, 2014). Consequently, developing a complete understanding of this sector required research on the competitiveness of 'downstream' firms (i.e. operators and service providers). Furthermore, the MSc study raised questions on the impact of wider framework conditions (i.e. governance) on the competitiveness of firms. Therefore, the focus of this thesis on the competitiveness, organisation and governance of the UK *space* sector builds on the research findings of a smaller, earlier study.

Since 2012, there has also been continued growth of the industry, as it has "consistently achieved growth of over 8.8 per cent per year" from 2007-2014 (Gov.uk, 2015). However, compared to other countries (such as France, America, Russia and China) *space* is still a relatively small sector in the UK (Table 1.1) (Venet, 2012). Nevertheless, as a strategic "enabler of growth in other sectors" (Gov.uk, 2015) and 'critical national infrastructure'[3] it warranted further research attention (CPNI, 2016).

Table 1: Global Comparison of UK *Space* Sector (2014)

	UK *Space* Sector (£m)	**% of OECD Estimate of Global *Space* Sector**
Space Manufacturing	907	1.8%
Satellite Operations	1,453	11.2%
Satellite Applications	9,253	10.3%
Total	**11,848**	**7.7%**

Source: Author (London Economics, 2015).

[3] The loss or compromise of 'critical national infrastructure' would result in a: i) major detrimental impact on the availability, integrity or delivery of essential services; and (ii) significant impact on national security, national defence or the function of the state (CPNI, 2016).

1.2 Research Aims and Objectives

The research was funded by the Economic and Social Research Council and addressed the following research aims and objectives:

Research Aim:

1. To identify and understand the economic geography of the *space* sector.
2. To understand the competitiveness, organisation and governance of the UK *space* sector.

Research Objectives:

1. To explore the geography of the UK *space* sector, through identifying the different actors involved and their spatial configurations.
2. To understand the key sources of competitiveness for UK satellite firms and to introduce orbital slots and frequency spectrum as competitive assets.
3. To explore the 'nature and extent' of the relationships between the manufacturers, operators and application providers involved in the UK *space* sector.
4. To investigate the impact of different forms and scales of public and private governance on different stages of production.

These research objectives will make two broad contributions to the academic debate. First, they will develop understanding of an industry which has been overlooked in the academic literature. Second, they will address specific gaps in the academic literature, relating to the conceptual framework applied.

1.3 Research Process

The production of *space* hardware and the provision of satellite applications are grounded in the economy. Consequently, features of the *space* sector, such as individual manufacturing and service tasks are common across other sectors, such as consumer electronics, automotive and aviation. However, there are also distinctive features of the sector, given that *space* is an extreme physical environment unlike any other, which poses complex technical challenges and financial risks to the firms involved (Fortescue, 2003; MOD, 2010; London Economics, 2015). Additionally, the provision of satellite-enabled applications is dependent on access to relevant orbital slots and frequency spectrum. These 'orbital resources' are very different to conventional tangible assets (such as facilities and equipment), in terms of physical presence and location, and access may provide monopoly advantages. These distinctive features meant that conclusions could not be made on the competitiveness, organisation and governance of the industry without primary, empirical research. Therefore, as well as desk-based research, eighty in-depth interviews were conducted with representatives from across the UK *space* sector (i.e. manufacturers, operators, application providers, government institutions, satellite insurance providers and *space* legal practitioners). Twelve pilot interviews were also conducted in Florida (31st March to 5th April 2014), to explore the viability of a US-UK cross-comparison. However, it was found that the US context (with regards to scale), is too different from the UK context to make a sensible comparison, given the time and resource constraints imposed on the study (Denscombe, 2002). Notwithstanding that this focus on a single national context limited the external validity of the findings, it meant resources were less stretched and that the data collected was "detailed, accurate and thorough" (OED, 2013).

To provide a complete understanding of the economic geography of the UK *space* sector, one cannot deal with competitiveness in isolation (as with the MSc study). Consequently, this thesis explores the competitiveness, organisation and governance of the sector, since understanding one of these research areas is integral to understanding another. For example, governance influences the “nature of competition” and organisation of production (Nachum, 1998:465). Each research area was defined and approached in different ways, following which they were combined to provide the overarching conceptual framework for the study. The definitions and approaches applied to each are outlined below.

Competitiveness is a ‘relative concept’ determined by a firm’s ability to deliver ‘superior’ yet profitable products which capture higher rents because of competitive advantages (Ajitabh and Momaya, 2004; Man *et al.*, 2002; Chikán, 2008; Kitson *et al.*, 2004). The approach to understanding competitiveness in this thesis is holistic, whereby a broad overview of firm-level competitiveness in the UK *space* sector is given, comparing competing explanations between different types of firms. This approach involves the adoption of theories from both the resource-based view (RBV) and evolutionary perspective, with contributions from other theories (such as institutionalist) addressing gaps in each (Barney, 1991; De Rassenfosse, 2012; Dubois, 2015; Walsh and Beatty, 2007; Bryson and Ronayne, 2014; Phelps and Fuller, 2016). The outcome of this approach is the identification of internal resources and external factors as a source of competitiveness for UK satellite companies (RBV), whist highlighting the routines which develop and access the internal resources (evolutionary perspective).

Organisation involves a set of decisions which manages the act of producing an output from a series of inputs (Walker, 2000; Lane and Probert, 2004). These decisions dictate: (i) the distribution of production tasks (Harvey, 2014; Coe *et al*., 2008; Ponte and Sturgeon, 2014); and (ii) the nature and extent of relationships with buyers/suppliers (Henderson *et al*., 2002; Gereffi *et al*., 2002; Hughes *et al*., 2008). To understand the distribution of production tasks in this thesis, a production project/task (PPT) approach is applied (Bryson, 2008). This avoids the 'overused' GPN network term and encourages a more balanced understanding of different network scales (Bryson, 2008; Gereffi, 1994; Henderson *et al.*, 2002; Coe *et al*., 2008; Ponte and Sturgeon, 2014). It also considers both manufacturing and service functions, which is valuable since both are involved in production in the *space* sector. To conceptualise the structure and character of buyer-supplier relationships (BSRs) in the UK *space* sector, the global value chain (GVC) governance typology is applied (Gereffi *et al*., 2005; Sturgeon, 2001; Henderson *et al.*, 2002). However, adjustments to this typology are required in order to address criticism and account for industry specific features. These adjustments include: (i) focussing on more than a single procurement moment; (ii) distinguishing between captive-buyers and captive-suppliers; (iii) prioritising the degree of coordination and power asymmetry of BSRs over the ability to codify information and supplier capability; and (iv) considering external governance factors.

Governance is a "system of rules" or "mechanism of decision making" imposed by public or private actors (Rosenau, 1995:13; Levi-Faur, 2012:9). It can be divided into two categories: (i) regulatory governance, which relates to constraints on firms' behaviour through regulations; and (ii) facilitative governance, which promotes economic activity and enables market creation (Mayer and Pickles, 2010:2). This thesis explores the impact of both forms of governance on the UK *space* sector. A polycentric approach theoretically frames the analysis, since this is best suited for identifying the multi-scalar actors involved (Coen and Thatcher, 2008; Kooiman, 2000). The polycentric approach identifies the interactions between the different scales of governance and compares the impact of each on the competitiveness of firms (Jessop, 2011: Jessop, 2004; Dunsire, 1993).

1.4 Structure of the Thesis

The argument advanced in this thesis is developed across eight chapters. Following the introduction, Chapter two examines the literature on *space*, competitiveness, organisation and governance. As a result of the breadth of the research objectives, the literature reviewed is not confined to one area of economic geography, but spans the 'relational', 'evolutionary' and 'institutionalist' debates. In addition, the literature on political geography is drawn upon to support an analysis of the geopolitical aspects of the *space* sector.

Chapter three then outlines the research design, approach and methods applied to the study. This chapter has four sections. First, the qualitative 'explorative' and 'in-depth' approach is discussed and an explanation is given to why this was appropriate to apply to an unexplored industry (Bryman, 2012; Onwuegbuzie *et al.*, 2012). Second, the primary methods of data collection are identified, namely: (i) desk-based research; and (ii) semi-structured interviews. Third, detailed descriptions of the ethical considerations, cases studied, sampling strategy and access strategies are outlined. Finally, the three stages of data analysis are explored, namely: (i) transcription and description; (ii) classification; and (iii) coding (Kitchin and Tate, 2000), before final remarks are made.

Chapter four begins by exploring the distinctive roles and characteristics of three separate but related segments or sub-sectors of the *space* sector: (i) manufacturers of *space* assets; (ii) satellite operators; and (iii) *space*-enabled service providers. The variations yet interdependence between these sectors are a particular focus, as this is critical for developing an understanding of the industry's organisation of production. The distinctive geography of *space* orbits and frequency spectrum are also explored, as this theme is an important wider framework condition of the *space* sector. This is followed by a discussion on ground geography, exploring the relationship between land surfaces and satellite orbits, with a focus on ground stations and launch sites. This contributes to the 'geography still matters' debate, as it highlights how satellite ground stations and launch sites in particular are restricted to particular locations (Warf, 2007; Howells, 2002; Buckley and Ghauri, 2004; Dupuy *et al.*, 2010; Sheldon, 2014). The chapter concludes by highlighting the interactions between the structure of the industry, *space* geographies and ground geographies.

Chapter five provides a necessary insight into the governance of the UK *space* sector, with a primary focus on the regulation and facilitation of the market by state policies (Gereffi and Mayer, 2006). It also identifies the contribution of private insurers and political lobbying to the governance of the industry, as it is important not to ignore their influence over industrial activity. The structure of the chapter follows the regulation and facilitation of five key processes, which precede the delivery to market of a satellite application. They are: (i) obtaining an orbital slot and frequency spectrum; (ii) satellite procurement; (iii) satellite insurance; (iv) obtaining a *space* licence; and (v) delivery of satellite-enabled application.

Chapter six explores the varying nature of BSRs at different phases of a satellite mission, through identifying different types of BSRs from the GVC governance typology (Gereffi *et al*., 2005). The chapter also highlights the overlap between Gereffi *et al*'s. (2005) 'five types', as there are exchanges in the UK *space* sector which have characteristics of more than one type of BSR. Additionally, there is an identification of the spatiality of the BSRs, comparing the exchanges that require geographic proximity with those that can be globally dispersed. The chapter's structure divides analysis between the sale of satellites and satellite-enabled applications, because of the differences in production tasks and firms involved. However, any links and feedback loops between the two sales are also identified, since the output of one is a core necessary input for the other.

Chapter seven investigates the internal resources that are a source of competitiveness for UK satellite companies, whilst highlighting the routines which develop and access them. It focusses on five internal resources, which were identified as key sources of competitiveness by the interview participants, namely: (i) orbital slots and frequency spectrum; (ii) heritage; (iii) innovative capability; (iv) networks; and (v) capital. The five resources and associated routines are discussed separately, but it is understood that they support and affect the performance of one another (Hölzl, 2005; O'Regan, and Sims, 2008). Routines can lead to path dependency, defined as the inability of a firm to "shake free of their history" and develop beyond their "established ways of doing things" (Martin and Sunley, 2006:400). Therefore, the chapter also explores where this occurs in the industry and where and how path dependency has been overcome.

Chapter eight concludes this thesis by highlighting its key theoretical contributions and what they mean for the way in which we approach industry studies. It first provides a variant of the conceptual framework (outlined in Chapter 2), with additions based on the research findings. The chapter also identifies what the *space* sector and policy makers can learn from the research findings. Finally, it explores opportunities for further research and outlines other actions which need to be taken.

CHAPTER 2

A PLACE FOR '*SPACE*' IN GEOGRAPHY: THE COMPETITIVENESS, ORGANISATION AND GOVERNANCE OF THE UK *SPACE* SECTOR

2.1 Introduction

Satellite-enabled applications play a critical role in economic and social activity. Nevertheless, little is understood about the industry which delivers these applications. The principal aim of this thesis is to contribute towards addressing this gap, by providing the first economic geography study of the UK *space* sector. It focusses on three aspects of the industry, namely: its competitiveness, organisation of production and governance. The starting point with these three research areas was firm-level competitiveness, since identifying what makes firms competitive is a core part of understanding their spatial configurations (Clark *et al.,* 2003). It was then recognised that outlining the industry's organisation of production and governance would be integral to understanding its competitiveness, since competitiveness, organisation of production and governance are so closely linked.

This chapter is divided into three key sections which highlight research gaps or limitations within the current academic understanding of the *space* sector. First, the academic literature on the *space* sector is introduced, since it is important to highlight what research has already been undertaken before identifying what is missing. This is followed by an examination of the literature on competitiveness, organisation and governance. Finally, concluding remarks bring together any related ideas from the first four sections and outline the conceptual framework through which the research questions are examined. The breadth of the research themes means that the literature is not confined to one area of economic geography, but instead spans the relational (Gereffi *et al*., 2005; Coe *et al*., 2008; Ponte and Sturgeon, 2014); evolutionary (Phelps and Fuller, 2016; Maskell and Malmberg, 2007; Boschma and Frenken, 2006); and institutionalist (Jones, 2014; Neilson and Pritchard, 2009; Nadvi, 2008) debates. In addition, political geography concepts and approaches (Prince, 2012; Rothsetin, 2012; Dolman, 2005; Jessop, 2004; Brenner, 2001) are incorporated, to reflect the importance of geopolitical influences on the *space* sector.

The review considers how despite society's increasing dependence on satellite-enabled applications, the *space* sector has been overlooked by economic geographers, meaning that along with other aspects, the competitiveness, organisation and governance of the satellite industry is not fully understood. Additionally, despite their relevance, the significance of *space* assets (such as orbital slots and satellite infrastructure) has been underplayed in the vertical geopolitics debate (Hewitt and Graham, 2015).

2.2. An Academic View of *Space*

Academic literature focussing on *space* as a subject of inquiry can be found across a range of disciplines (i.e. politics, law and engineering). For example, there is a focus in the policy literature on '*space* policy' within a global, European and even UK context (Axelrod, 1985; Sadeh, 2002; Braunschvig *et al.*, 2003; Abbey *et al.*, 2005; Bormann and Sheehan, 2009). On European *space* policy for example, research has explored the barriers to and enablers of satellite services (Teodora and Bruston, 2009); contract and procurement practices (Smith and Baumann, 2011); and institutional governance frameworks (Wouters and Hansen, 2013). Alongside the policy literature, the legal literature has focussed on the "laws that govern *space* activity" (Mosteshar, 2010:359; Shackelford, 2009). For instance, Thompson (1996), Cahil (2000), Copiz (2001) and Stuart (2009) investigate the laws and legal challenges in respect of securing an orbital slot, since *space* is considered a 'commons resource' which prohibits sovereignty claims. Additionally, there is an engineering literature which explores the 'technical fundamentals' involved in the delivery of *space*-enabled applications, outlining 'recent technological developments' (Kolawole, 2013: *xi*; Fortescue *et al.*, 2011; Cho *et al.*, 2013). However, these academic discussions have ignored the 'grounded nature' of the *space* industry, by conceptualising *space* as though it is isolated from the world economy. Therefore, the literature now needs to identify and explore the different ways in which *space* is exploited as an economic asset and the characteristics of the industry which drives this.

Space also featured in the early human geography literature. For example Livingston (1992) explores the relationship "between the terrestrial and the celestial" (MacDonald, 2007:595). However, in more recent years, geographers have considered the subject of *space* as being "too absurd, odd and abstract" (Collis, 2009:49). Consequently, despite their global significance, satellites have become "a black hole in the geographical literatures on communications" (Warf, 2006:2). The attitude towards *space* and its relevance to human geography is changing however, as it is appearing less remote because of the development of lower cost access, and more familiar as the "information-intensive and hypermobile world economy" increasingly depends on satellite-enabled applications (Castells, 1996; cited in Warf, 2007:385). This emergence of satellites as a "powerful component of global economies" (Collis, 2009:29) has been matched with the realisation that whilst "…satellites circulate in outer *space*, their origins and impacts occur very much on the ground." (Warf, 2007:385). There is evidence therefore of "a critical geography of *space"* beginning to emerge (MacDonald, 2007:593).

Macdonald (2007:592) has been particularly influential in driving the interest in *space* as a subject of geographical inquiry, arguing that it should both challenge and reanimate "the 'geo' of geography". In response, Beery (2012:25) examined the politics of US private *space* travel and the implications of its privatization. Similarly, Wang (2009:433) investigated "geopolitical interactions between Europe and the United States (US) in large-scale outer *space* application programmes", arguing that outer *space* is "a new 'space' for transatlantic interaction". Collis (2009:47) also explored the "multiple and dynamic nature of geographical *space*" and how extending the field of geography into outer *space* furthers the concept of 'spatiality'. Collis (2009) was particularly concerned with the 'tangled geography' of the geostationary orbit, as a geopolitical and contested space. This evidence of spatiality was then extended in a subsequent paper to include the geopolitics and legal status of Mars (Collis and Graham, 2013). These discussions however, have been too dominated by accounts of the geopolitics 'up there', without due consideration of the industry driving the use of *space* 'down here'.

To Macdonald (2007), *space* is relevant to geography because of its 'sociality' or use in operations which maintain the state, ranging from accessing information to the conduct of military warfare. The militarisation of *space* is particularly significant, as it is accompanied by geopolitical struggles, which are "too serious to pass without critical comment" (MacDonald, 2007:593). There is a hidden economic geography here, since national security and privacy concerns mean that use of military satellites is not widely publicised and the industry behind the applications is not fully understood. Warf (2007:385-386) also found satellites to be a major component of military operations, as well as being "entrenched in other power relations", like the control held by the producers and users of the satellite technology over the global information infrastructure. This study of the relationship between *space* and "political and military policy and strategy" has been labelled 'Astropolitics' (Dolman, 2005:15).

Astropolitics is an example of 'vertical geopolitics', the recognition of the "increasingly vertical and volumetric nature of the urban environment" (Hewitt and Graham, 2015:925). Vertical geopolitics is important because otherwise geography would remain a "flat discourse" which fails to understand territories and regions "in terms of height and depth" (Weizman, 2002:3; Elden, 2013:49). As identified by Graham and Hewitt (2013:925), there are numerous examples in the literature of the "volumetric nature of the urban environment", which support the vertical geopolitics work. For instance: Sloterdijk (1998) explores the role of height in military power operations; Ireson (2000) and McNeil (2005), the verticality of our cities with the dominance of the urban skyscraper; and Choy (2010), the politics of urban air. Scott (2010) also identifies the significance of satellite observation and surveillance. However, the significance of *space* as an example of verticality has overall been underplayed, considering society's increasing dependence on satellite applications. Addressing this research gap would develop "stronger theorizations of verticality" (Scott, 2008:185), whilst also strengthening the understanding of a critical sector.

The academic literature on the *space* sector has shown that *space* is regulated and influenced by geopolitics (Dolman, 2002), whilst the provision of satellite infrastructure is motivated by civil, science and defence needs (Kolovos, 2002; Corsini *et al*., 2006; Tóth *et* *al.*, 2005). The outcome is an understanding of the satellite industry which underplays the 'grounded nature' of the *space* sector and how incorporated it is into national economies. Consequently, the economic geography of the *space* sector remains an "undeveloped avenue of inquiry", despite satellite-enabled services being both a route to capital accumulation and increasingly relied upon by society (MacDonald, 2007:611).

To further the economic geography of *space* this research explores the competitiveness, organisation and governance of the UK satellite industry. Economic geography is the primary research lens, whilst political geography informs the governance theme. The geopolitical literature is important, since an entirely economic lens would be insufficient in reflecting the geopolitical influences which impact on *space*. The next section examines the competitiveness literature as a key theme to framing the research.

2.3 Understanding Firm-Level Competitiveness

Satellite technology contributes immeasurably to creating the society that we live in today, as it: (i) generates GDP; (ii) provides employment opportunities; (iii) supports military operations; and (iv) increases individual and business productivity (Gov.UK, 2015b; OECD, 2014; ESA, 2014). These contributions are indicative of the continued supply of satellite services being "of significant economic importance" to the UK economy (London Economics, 2015:1). Nevertheless, understanding the competitiveness of the *space* sector has been overlooked by the academic literature. Empirical research into the competitiveness of satellite companies is required to address this gap. This section reviews literature on firm-level competitiveness to provide a conceptual framework for this part of the research.

Competitiveness originates from the Latin word ‘competer’, meaning “involvement in a business rivalry for markets” (Ambastha and Momaya, 2005:46), and is synonymous with economic strength. It is a ‘relative concept’, determined by a firm’s ability to deliver ‘superior’ yet profitable products, which capture higher rents because of competitive advantages (Ajitabh and Momaya, 2004; Man *et al.*, 2002; Chikán, 2008; Kitson *et al.*, 2004). Research on competitiveness varies considerably across the literature because it is a broad concept, which covers both macro and microeconomic issues. Balkyte and Tvaronaviciene (2010:359) for example, classified six different scales of competitiveness: i) firm-level; ii) sector/industry-level; iii) regional (local area to city region); iv) national; v) bloc competitiveness (i.e. Europe); and vi) global competitiveness. For this study, the ‘firm-level’ is the scale of analysis. However, all six scales interact and impact on one another. For example, the competitiveness of an industry is determined by the competitiveness of its firms. Similarly, firm-level competitiveness is influenced by external factors or wider framework conditions on a broader scale, including the regional or national competitive context.

There are numerous firm-based perspectives, including the: (i) institutionalist (understands the firm as “the site of rules and routines”); (ii) network (“envisage[s] the firm as embedded in socially constructed networks”); (iii) learning; (iv) competences or resource-based view (RBV) (“emphasis on resources and learning”); and (v) evolutionary (focusses on business change and organisational routines) (Taylor and Asheim, 2001:316). There is overlap between these perspectives, but each provides a different insight into the “nature and functioning of the firm” (Taylor and Asheim, 2001:315). How appropriate each of them is to apply to a study depends on the research context. In this case, it was the intention of the researcher to provide a broad overview of firm-level competitiveness, exploring a range of competing explanations. Consequently, it was important that the theoretical approach was as holistic as possible. Therefore, the RBV was applied as a firm-based perspective. The 'network' and 'learning' approaches feed into the RBV. Theories from the evolutionary perspective were then blended with the RBV, with contributions from the intuitionalist perspective addressing gaps in both. Blending two theories means both provide an element and are one part of a wider solution. In consequence, this thesis identifies the internal resources which are a source of competitiveness for UK satellite companies, whilst highlighting the routines which develop and access these resources. The remainder of this section reviews the literature relevant to these theories and justifies and explains the blended theoretical approach developed in this research.

2.3.1 Understanding Firm-Level Competitiveness: the Resource-Based View (RBV)

Understanding how it is that companies compete requires consideration of a whole series of price-based (i.e. low labour and energy costs) and non-price-based (i.e. design, location, brand) factors (Oh and Rhee, 2008; Seyoum, 2007; Cainelli *et al.,* 2006, John and Pouder, 2006; Bryson *et al.*, 2013; Voulgaris and Lemonakis, 2014; North, 2015). These factors offer competitive advantages, which enable firms to capture higher rents than their competitors. It is possible for firms to develop these factors and "improve their competitive position" over time (Kitson, 2004).

In today's global economy, UK firms are increasingly pressured by competitors based in lower cost production locations, who are able to market products at much lower prices (Petrick *et al.*, 1999; Bryson and Taylor, 2010). Therefore, whilst cost-control remains important, UK companies increasingly rely on non-price based advantages to distinguish themselves from lower price competitors (Bryson and Rusten, 2011; Billing, 2013). Given that the RBV focusses on non-price-based advantages, it is appropriate to apply it to this research on a UK industry. The breadth of the approach is also likely to be able to cope with the complexity of the *space* industry and the variety of sectors involved, including *space* manufacturing, satellite operations and satellite applications. These sectors all manage their own production projects and individual sets of resources.

The RBV is a firm-level approach, which argues that non-price based advantages are founded upon the internal resources of firms (Barney, 1991; Peteraf, 1993; Ronayne, 2015:196). To Petrick *et al.* (1999) and others (Haanes and Fjeldstad, 2000; Surroca *et al.*, 2010 etc.), resources that are intangible (non-physical) are often the most advantage-creating, since firms develop them over time. Therefore, they cannot be readily purchased or imitated by competitors, creating a long term or sustainable advantage (Bromiley and Rau, 2016; Fahy, 2000).

Examples of intangible resources identified in the literature can be divided into four categories: (i) intellectual property assets; (ii) organisational assets; (iii) capabilities; and (iv) reputational assets (Galbreath, 2005) (Table 2.1).

Table 2.1: Examples of Intangible Resources Identified in the Literature.

Categories	Examples of Intangible Resources and Associated Literature
Intellectual Property Assets	- Copyrights, patents and trademarks (Clark, 2013; De Rassenfosse, 2012; Martin-de-Castro *et al.*, 2011; Hall, 1993; Bontis, 2001; Marr *et al.*, 2004).
Organisational Assets	- A firm's networks or 'relational ties' with business actors (i.e. customers, suppliers and competitors), which are strategically formed to address a particular need, or randomly emerge from social interactions (Henry, 2013; Dubois, 2015; Rusasnen *et al.*, 2014; Hervas-Oliver and Albors-Garrigos, 2009; Jones and Craven, 2001; Kingsley and Malecki, 2004.). - Networks can be either formal (tied to an agreement that coordinates their activities), or informal (no agreement, just mutual interests) (Kingsley and Malecki, 2004).
Capabilities	- Innovativeness (Phelps and Fuller, 2016; O'Cass and Sok, 2013; Voulgaris and Lemonakis, 2014; Vanchan and Bryson, 2015; Reeves and Deimler, 2011) - Knowledge and skills of employees (Collins and Clark, 2003; Bueno *et al.*, 2010; Sveiby, 2001; Kessler *et al.*, 2000; Mårtensson, 2000).
Reputational Assets	- Corporate reputation and brand equity (Surroca *et al.*, 2010; Olavarrieta and Friedman, 2008; Walsh and Beatty, 2007; Caruana, 1997). There are two parts to corporate reputation: the impression of the company (influenced by financial stability etc.) and the impression of the products (quality level and innovation etc.) (Caruana, 1997; Fombrun and Shanley, 1990).

Source: Author (Galbreath, 2005).

To O'Regan, and Sims (2008:410), the source of firm competitiveness is often "multifactorial" and "cannot be attributed to only one resource". Consequently, RBV research will often investigate the competitive advantages created by multiple intangible resources. For example, patents (a "codified form of an invention constituting legal property") grant exclusive rights to a product or process and are used as a "mechanism for asserting dominance and maintaining control in markets" (Clark, 2013:65). Meanwhile, networks secure inputs, outputs and new opportunities for firms and in doing so "add value, generate wealth and improve perception" (Hervas-Oliver and Albors-Garrigos, 2009; Henry, 2013:94; Álvarez *et al.*, 2009). Networking is particularly valuable for smaller or younger firms, as it broadens their limited resource base and helps them to offset "some of their fragility" (Atterton, 2007:230).

Additionally, innovativeness is an advantage-creating resource, described as a capability for renewing either a firm's products or processes through the "commercial application of new knowledge" (Love *et al.*, 2011:1438). These changes are identified as 'innovation' and can either be incremental (i.e. minor improvements) or radical (i.e. new "engineering and scientific principles") (Summerer, 2011:7). Both incremental and radical change can be advantage creating, yet radical innovation often has a greater impact (Parida *et al.*, 2012; Lengnick-Hall, 1992; Ettlie *et al.*, 1984). Innovation creates a competitive advantage as it is a means for firms to adjust to change and improve "key buying criteria" (i.e. reliability, aesthetics, delivery time and costs) (Hall, 1993:607). A firm's innovativeness is dependent on its access to distinctive assets, such as employee knowledge (Vega-Jurado *et al.,* 2008; Damanpour *et al.,* 2009). Knowledge can be developed through education and networking with external knowledge actors, including universities, research laboratories and other firms (Fritsch and Slavtchev, 2007; Roper and Hewitt Dundas, 2012). A networking approach to innovation is identified as 'open', which contrasts to 'closed innovation', where firms are independent and solely depend upon their in-house resources (Chesbrough *et al.*, 2006; Chesbrough, 2010). Open innovation suggests that intangible resources (such as networks and innovativeness) may interact and reinforce one another.

In addition, corporate reputation differentiates firms from their competitors, by signalling quality, reliability and credibility to consumers (Galbreath, 2005; Boschma and Martin, 2010; Turban *et al.*, 1998). Corporate reputation is identified as "observers' collective judgement of an organisation" (Barnett *et al.*, 2006:34). This judgement is based on personal experiences or secondary information, which highlights a range of firm-based attributes (Walsh and Beatty, 2007).

2.3.2 Understanding Competitiveness: Tangible or Physical Assets

The RBV identifies intangible assets and dynamic capabilities as factors which most contribute to non-price based competitiveness (Barney, 1991; De Rassenfosse, 2012; Dubois, 2015; Walsh and Beatty, 2007; Bryson and Taylor, 2010; Phelps and Fuller, 2016). However, 'tangible' or physical assets that "can be touched, smelt, heard, tasted and/or seen" also contribute to firm competitiveness (Hooley *et al*., 1998:97). Examples of tangible assets include 'real property' and equipment (Galbreath, 2005). This research explores the value of physical assets in the *space* sector, which is a valuable contribution to the RBV literature, as it has previously argued that tangible resources are a "relatively poor source of advantage" (Fahy, 2002:64).

A firm's real property includes its buildings and land, which can be owned or leased. It is commonly an appreciating asset, which will accrue more value over time (Scott, 1980; Guy, 1997). This 'value' goes beyond monetary terms and "exists on two distinct, but related levels": (i) use value (from accommodating production activities); and (ii) exchange value (Massey and Catalano, 1978; Bryson, 1997:1440). Both types of value depend on the property's location decision, which is consequently a 'primary determinant' of firm competitiveness (Clark and Wrigley, 1995, 1997; Beugelsdijk *et al.*, 2010). There are a number of factors which influence location decisions and, depending upon the firm/sector, they offer "differential locational advantages" (Scott, 1980:4). These factors include: site costs, customer proximity, transport connectivity, labour supply, government support, environmental factors, proximity to knowledge actors and utility infrastructure (Ansar, 2013; Jo and Lee, 2014).

In the satellite industry there is an additional location decision to make: where to position satellites in outer *space* (orbital slots) (Thompson, 1996). Similarly to real property there are differential locational advantages associated with orbital slots (Dolman, 2002). Mosteshar (2013:2) for example, argues that "the most desirable" slots are in the "geostationary orbit (GEO), about 37,000 kilometres above the Earth's surface". Collis (2009) described this orbit as a contested space. However, Collis's (2009) contribution came from a geopolitical perspective, thus the economic geography of orbital slots remains undeveloped. Consequently, there are unanswered research questions concerning: (i) the challenges in respect of acquiring orbital slots; and (ii) the relative advantages of securing more desirable slots. For instance, Collis's (2009) argument that the GEO orbit is a contested space may be challenged with evidence that the slots are controlled by those who got there first. This relates to the theory of first-mover advantage (FMA), whereby a firm earns "above average profits" by "entering a market first" or "entering the market in a way that thwarts other firms' attempts to compete" (Finney *et al.*, 2008). The thesis also identifies any similarities between real property and orbital resources (slots and frequency spectrum), such as them both having "differential locational advantages" (i.e. varying rates of profit depending on location) (Scott, 1980:4). This link between property on Earth and orbital slots/frequency spectrum in *space* contributes to the research on vertical geopolitics, which explores the 'height and depth' of territories (Weizman, 2002: 3; Elden, 2013:49).

2.3.3 Understanding Competitiveness: The Evolutionary Perspective

Sections 2.3.1 and 2.3.2 have outlined why it is appropriate to apply the RBV to this research, providing its focus on intangible resources is extended to tangible assets. Nevertheless, the RBV literature has been criticised for being too static and failing to account for change (Priem and Butler 2001). In contrast, the evolutionary perspective is more “dynamic”, highlighting the impact of past decisions and firm adaptations on firm competitiveness (Bryson and Ronayne, 2014:475). Consequently, the approach to understanding competitiveness in this thesis is to apply theory from both the RBV and evolutionary literatures.

The evolutionary perspective focusses on organisational routines and how they shape “intrafirm and interfirm processes” of “business change” (Phelps and Fuller, 2016:123). Routines are the “day-to-day dealings” or “regular and predictable behavioural patterns” of a firm which have “built up over time” (Jensen, 2010:2048; Maskell and Malmberg, 2007:605; Boschma and Frenken, 2006:277). They guide actions and decision-making processes by locking firms into strategies and behaviours (Maskell and Malmberg, 1999; Christopherson and Clark, 2009; Cecere *et al.*, 2014; Essletzbichler and Rigby, 2007). A firm’s strategy and behaviour is important because it influences its development of / access to resources which are sources of competitiveness (Bryson and Ronayne, 2014). For example, realising new opportunities through innovation requires “relevant learning routines” (Bessant *et al.*, 2012:1108).

It is possible to blend the RBV and evolutionary theories, since the scales of analysis for both are on the firm level and their arguments do not conflict. For instance, the RBV is about the identification of resources which provide competitive advantages (Knoben, 2011;

Barney, 2011; Fahy, 2000), whereas the evolutionary perspective is about processes (routines) which lead to the development or management of resources (Bryson and Ronayne, 2014; Boschma and Frenken, 2006). There is no reason why both routines and resources cannot be considered when researching the competitiveness of UK satellite firms.

Routines can also lead to path dependency, defined as the inability of a firm to "shake free of [its] history" and develop beyond its "established ways of doing things" (Martin and Sunley, 2006:400). This can inhibit innovation and the potential diversification of a firm's resource base (Martin and Sunley, 2003; Isaksen, 2014). Consequently, certain routines can negatively impact on firm competitiveness (Sydow *et al*., 2009; Turco and Maggioni, 2014). For example, they can cause 'technological lock-in', where firms become locked into technologies (i.e. products or processes) which are not necessarily "superior to alternative solutions" (Cecere *et al*., 2014:1041). This lock-in can mean firms "struggle to compete and survive", as competitors make disruptive changes and develop superior technologies (Cecere *et al*., 2014:1042). Therefore, this research considers the positive and negative impacts of routines on firm-level competitiveness. Although technological lock-in is difficult to overcome, it is "often a temporary phenomenon from which escape is possible" (Van der Vooren, 2012:101). For example, industry and wider government policies can provide incentives and support firms in overcoming negative lock-in (Turco and Maggioni, 2014). This is an example of how external factors can unlock routines and impact on firm-level competitiveness. The next sub-section reviews the literature on these external factors and outlines how they are also considered in the research.

2.3.4 Understanding Competitiveness: External Factors

The unique bundle of resources and capabilities which make UK satellite firms competitive are 'territory specific', as they are partly a product of the 'institutional regime' of the UK economy (Martin, 2000). A 'regime' is based on the institution's environment (i.e. informal conventions and formal rules/regulations) and arrangements (i.e. organisational forms, including markets and regulatory agencies) (Martin, 2000). Conventions are defined as "a broad group of mutual expectations", which guide action and provide forms of coordination, such as an industry's product and process-related quality standards (Ponte and Gibbon, 2005:6). These emerge in response to a perceived need for coordination (Marescotti, 2000; Lewis *et al.*, 2002; Levy, 2001). Not all conventions are as formal as standards however; other examples include expectations on appropriate product prices, delivery times, technical requirements and necessary resources. These quickly become "common knowledge"; are often "rigid and unchanging" and encourage path dependency (David, 1994:210; Becker, 1984:31). In addition to institutional conventions and arrangements, firm competitiveness is affected by external factors (Porter, 1990; Martin and Sunley, 2003; Shafaei *et al.*, 2009).

External factors were identified in Porter's (1990) diamond on national competitive advantage, "one of the most prominent and frequently applied approaches" to competitive research (Dögl *et al.*, 2012:193). They relate to the public governance of the industry; the 'system of rules' or 'mechanism of decision making" imposed by the state (Section 2.5) (Rosenau, 1995:13; Levi-Faur, 2012:9; Mayer and Pickles, 2010:2). This highlights the overlap between competitiveness and governance research and supports the decision to focus on both in this thesis. There have been criticisms of Porter's external factors however, which should be considered when applying them to this research. Dunning

(1993), Nachum (1998:460) and Rugman and Verbeke (1993:283) for example, criticised the single nation focus of external factors, which underestimates the significance of other national and supranational influences. In response to this criticism, this thesis explores governance on a global, European and multi-national scale.

2.3.5 Competitiveness of the UK *Space* Sector

The review of the competitiveness literature identified that despite the ‘significant economic importance’ of the satellite industry, the *space* sector remains unexplored in the economic geography literature (London Economics, 2015). Consequently, empirical research into the competitiveness of satellite companies is required to address this gap. The approach to understanding firm-level competitiveness applies theory from both the RBV and evolutionary literature. Therefore, the research identifies the internal resources which are a source of competitiveness for UK satellite companies, whist highlighting the routines which develop and access these resources.

The literature review highlighted how the sources of firm-level competitiveness are often ‘multifactorial’ and dependent on interactions between a range of internal resources (O’Regan and Sims, 2008; Porter, 1990; Dunning, 1993). Consequently, the thesis explores the competitive value of: (i) intellectual property assets; (ii) organisational assets; (iii) capabilities; (iv) reputational assets; and (v) tangible assets (Galbreath, 2005; Hooley *et al*., 1998; Porter, 1990; Porter, 1992). The research also introduces orbital slots/frequency spectrum as competitive assets and provides empirical evidence of the role government policies play in influencing the “nature of competition” (Nachum, 1998:465). The next section explores the organisation of production, another contributing factor to firm-level competitiveness.

2.4 Organisation of Production

Production is the act of achieving an output from a series of inputs and involves a set of decisions which manage this process (Walker, 2000; Lane and Probert, 2004:246). These decisions dictate: (i) the distribution of production tasks; and (ii) the nature and extent of relationships with buyers/suppliers. Understanding the organisation of production is an important part of exploring firm-level competitiveness, since organisation and competitiveness are explicitly linked. For instance, a firm's decision about whether to outsource its activities is part of their competitive strategy. Similarly, the character of a firm's relationship with its buyers and suppliers is an external factor, which impacts on its competitiveness. Therefore, exploring the organisation of UK satellite companies would contribute to understanding their competitiveness. Additionally, the organisation of production is an obvious route of enquiry for exploring the spatial configurations of the UK *space* sector (Clark *et al*., 2003). This section reviews the literature on the distribution of production tasks and the nature and extent of buyer-supplier relationships to develop a conceptual framework for the organisational part of the research.

2.4.1 Distribution of Production Tasks

A common characteristic of the organisation of production is the separation of activities into simpler tasks, carried out by different individuals or firms. This concept was first defined by Adam Smith (1776) as the 'division of labour'. A common outcome of the division of labour is that related production tasks are physically separated or 'fragmented', as they are divided between firms in disparate locations (Gereffi *et al.*, 2005; Arndt and Kierzkowski, 2001; Slepniov *et al.*, 2014). Traditionally, these firms were located within close proximity. However, as the "expertise and labour skills" of different nation states are increasingly utilised (Bryson, 2008:265), production systems involve "diverse constellations" of globally dispersed economic actors (Ponte and Sturgeon, 2014:199).

To Harvey (2014:15), the division of labour continues to be relevant to modern production and should be "positioned as one of the fundamental features of what capital is all about". Consequently, over the past two decades, a rich literature has emerged to explain the distribution of production tasks and how constellations of economic actors are organised (Lüthi *et al.*, 2010). This literature, from relational economic geography, management and organisation studies, has identified several competing conceptual frameworks, including: (i) the Global Commodity Chain (GCC); (ii) the Global Value Chain (GVC); and (iii) the Global Production Network (GPN) (Gereffi, 1994; Gereffi *et al*., 2005; Henderson *et al.,* 2002; Coe *et al*., 2008; Coe, 2012; Ponte and Sturgeon, 2014).

The 'commodity chain' was the first out of the three conceptual frameworks to emerge and was defined by Hopkins and Wallerstein (1986:159) as "a network of labour and productive processes whose end result is a finished commodity". This initial work gave rise to Gereffi's seminal chapter in his 1994 book, which identified that 'commodity chains' can be globally dispersed (Birch, 2008). Since then, several researchers have replaced GCC with GVC because of the associations with commodity to standardised products, which fails to account for other more diverse production tasks (Henderson *et al.* 2002). Additionally, the use of the term 'value' (the 'V' in GVC) more adequately captures the "value added" concept (Ponte and Sturgeon, 2014:202). The chain metaphor (the 'C' in the GVC and GCC) remained, as it emphasises the "sequential and inter-connected" organisation of production, as inputs are transformed into outputs and distributed for final consumption (Henderson *et al.*, 2002:439). However, in contrast to the GCC framework, the GVC framework highlighted that production has become 'more network-oriented' and is 'less vertically integrated', and is therefore more inclusive of the "full range of activities that firms and workers do to bring a product" into use (Lüthi *et al.*, 2010:118). Bryson (2008a:41) argued that this involves a 'collection' of different businesses, including "suppliers, financers, manufacturers and distributors".

Despite the recognition by the GVC framework of the broad range of production tasks, the 'chain' approach limits the focus to the "linear/vertical dimension of a production network", whereas, in reality, networks are far more complex (often multi-directional, multi-dimensional and multi-layered) (Coe *et al.*, 2008:274). Consequently, the Manchester school of economic geographers developed an alternative 'Global Production Network' (GPN) approach, which considers "all relevant actors and relationships" (MacKinnon, 2012:227). Coe *et al.* (2008:274) defined GPNs as a:

> "…nexus of interconnected functions, operations and transactions through which a specific product or service is produced, distributed and consumed".

The organisation and geography of these networks are in a constant state of flux and extend globally. The GPN approach is more appropriate than the GCC/GVC frameworks for analysing the distribution of production activities because it accounts for a more diverse range of economic actors (Bryson, 2008). Additionally, it adds value by considering the nature and extent of the actor's relationships (Henderson *et al.*, 2002; Sturgeon, 2001).

Nevertheless, there are weaknesses in the GPN approach. For example, it "foregrounds global relationships as being the most important element in production networks", underestimating the significance of local associations (Bryson, 2008:280). Additionally, 'network' is an overused term with "too many different associations" (Bryson, 2008:280).

Consequently, Bryson (2008a; 2008b:281) argued that a ‘Production Project/Task’ (PPT) approach is a more appropriate conceptual framework. It focusses on understanding the value creation and geography of “separate but related tasks”, which are blended or bundled into production projects (Bryson, 2009:37). Similarly to the GPN and GVC approaches, the PPT approach involves conceptual and empirical exploration of:

(i) the influences over “geographic location and distribution” of production activities (Pavlinek, 2012:284);

(ii) the impact of embeddedness or the “anchoring of the production activities in different places” (MacKinnon, 2012:229); and

(iii) the “organisation and distribution of power” between different actors, including identifying who influences “decisions and resource allocations” and who retains the most value (MacKinnon, 2012:229; Mahutga, 2014:160).

However, the PPT approach avoids using the term ‘network’ and encourages a more balanced understanding of relationships across different geographic scales (not just the global scale).

Furthermore, the PPT approach does not focus solely on a “specific product or service” (Coe et al., 2008:274), but instead production projects, which include both manufacturing and service activities (Bryson, 2009). This is an appropriate framework to apply to research on the *space* sector, since it involves both the manufacturing of physical infrastructure and the delivery of satellite-enabled services. The manufactured hardware is “a vehicle” for accessing the applications or service, which is an example of ‘service encapsulation’ (Bryson, 2009:34). A product such as this, which integrates manufacturing and service functions, is identified as a “hybrid product” and is the output of “hybrid production systems” (Neely, 2008: 107). There are two forms of service inputs in hybrid production systems: (i) production-related; and (ii) product-related. Production-related services are ‘intermediate inputs’ and include business and professional services; whilst product-related services “directly and indirectly support customers in their purchase and use of a product” (Bryson, 2009:20). Tukker (2004) divides product-related services into a further three categories (Table 2.2). Depending upon the product, production systems involve different quantities and forms of service input (Smith and Maull, 2014; Neely *et al.*, 2011).

Table 2.2: Three Forms of Product-Related Services.

Service Form	**Description**
Product-oriented services	The services are an addition to the primary products sold, for example maintenance contracts and consultancy advice.
Use-oriented services	The product stays in ownership with the provider and is made available through the product: leasing, renting and polling (simultaneous use of the product). The advantage for the user is that they do not have to cover the upfront payment of the product.
Result-oriented services	The buyer and the provider agree on a ‘functional result’, not a ‘pre-determined product’. The user pays for the output of the product (Pay Per Service Unit), for example data.

Source: Based on Tukker (2004:248)

The consideration of service functions by the PPT approach is a significant contribution, since despite the ‘range of service functions’ involved with modern production, the GVC and GPN literature has often ignored service tasks (Coe *et al.*, 2008; Walker, 2000). In response to this, Coe (2014) shifted “conceptual and empirical attention away from manufacturing industries” towards the service industry, through exploring the role of financiers in the production process (Neilson *et al.*, 2014:6). However, further empirical research is still necessary in order to understand the role of services in production projects; applying the PPT approach to this study helps address this gap. Additionally, academics and policy makers lack a cross-functional perspective, as they often discuss manufacturing and service tasks independently (Ernst and Kim, 2001; Henderson *et al.*, 2002; Slepniov *et al.*, 2014). Empirical evidence from this research on service encapsulation and hybrid production systems will help challenge this separation of manufacturing and service tasks.

However, the PPT approach is subject to some limitations. For instance, whilst the approach recognises that the output of one production project is often the input of another, there is limited detail on what these exchanges might entail. In response to this gap, this thesis explores the "various forms of backward and forward linkages" between production projects, as well as within them, by combining the PPT framework with insight from the netchain literature (Bryson, 2009:42).

As part of the GPN recognition of "wider sets of non-linear/horizontal relationships" in production, the netchain literature provides a multi-dimensional network perspective (Coe *et al.,* 2008:275). It does this by outlining a layering model to analyse both horizontal (transactions in the same layer) and vertical (transaction between layers) ties, as well as how they relate to one another (Lazzarini *et al*., 2001). Fransman (2002) applied this to the telecommunications industry and identified the suppliers, manufacturers, distributors and consumers in that industry as separate, vertical layers, with their own horizontal ties. This model would be valuable to apply alongside the PPT approach because it would ensure that the interactions between production projects (vertical ties) were analysed and not just those within projects (horizontal ties). To Coe *et al*. (2008:275), this "approach also emphasizes the complex nature of the interdependencies that exist within production networks". Nevertheless, the mutual reliance between vertical layers and their impact on horizontal ties could be expressed more explicitly. This is achieved by linking the structure of the *space* sector to the 'contextualist metaphor' of texture (Fineman and Hosking, 1990).

Texture is "viewed analogically as a weave or web of interacting elements", signifying 'connectedness in action' and an "endless series of relationships which continually move into each other" (Fineman and Hosking, 1990:574; Cooper and Fox, 1990:575). At present, this analogy has only been applied to social interactions in a micro context; between workers and their workplace contexts for example (Gherardi and Strati, 1990:605). However, the principle of drawing attention to "the dynamics of interaction between parts as opposed to the conception of parts as relatively independent sub-systems" fits with identifying the interdependencies between vertical ties (production projects) (Cooper and Fox, 1990:575). A texture analysis would also consider the contextual framework, since "the support of every texture lies in its context" (Cooper and Fox, 1990:576). This would involve considering external factors that impact on the production projects, including governance.

Therefore, the theoretical approach to analysing the distribution of activities in the *space* sector is a combination of the PPT, netchain and texture models. The next sub-section reviews the literature on the nature and extent of buyer supplier relationships, as this is also a critical part of the organisation of production.

2.4.2 The Nature and Extent of Buyer/Supplier Relationships

The nature and extent of relationships with buyers and suppliers (known as 'industrial governance') is part of the organisation of production of firms and is at the centre of much of the GVC and GPN literature (Henderson *et al.*, 2002; Gereffi *et al.*, 2005; Coe *et al.*, 2008; Hughes *et al.*, 2008; Nadvi, 2008). This explores the rules set by supply relationships and the transfer of 'risk and cost' between firms in value chains (Sturgeon 2001; Gereffi *et al.*, 2005).

The common approach to framing an analysis of buyer-supplier relationships (BSRs) is the use of a typology, which identifies 'ideal types' of BSRs (Gereffi *et al*. 2005; Vesalainen and Kohtamaki, 2015; Duffy, 2008; Bensaou, 1999). Ideal types are categories, classes or groups of a given phenomenon, identified by common characteristics which best represent them (Cohnman, 1965; Burger, 1978; Zaefarian *et al*., 2011; Cannon and Homburg, 2001; Ulaga and Eggert, 2006). The advantage of a typological approach is that it encourages "a variety of different relationship characteristics" to be considered simultaneously (Cannon and Perrault, 1999:440). Consequently, typologies are now a key conceptual tool commonly applied to social science research, with several of them focusing on BSRs. For example, in the business management and marketing literature alone, a "reported 32 typologies and taxonomies of business relationships" have been developed (Saccani *et al.*, 2014:227).

Similarly, in economic geography the GVC governance literature has identified a series of BSR typologies (Gereffi, 1994; Gereffi *et al.*, 2005; Ponte and Sturgeon, 2014). Initially, the GVC governance literature made a simple distinction between relationships in a buyer-driven and a producer-driven chain (Gereffi, 1994). However, this dichotomy was insufficiently representative of the "diversity of inter-firm relationships that exist" (Gibbon *et al.*, 2008:332). In response, Gereffi *et al.* (2005) developed an alternative fivefold typology of BSRs, which extended Gereffi's (1994) dichotomy with intermediary or 'in-between' relationship types. The five types exist along a continuum with market and hierarchy at opposite ends of the spectrum, and modular, relational and captive in-between (Gereffi *et al*., 2005) (Table 2.3). Like the buyer-driven and producer-driven model, this is "grounded in transaction cost economics", but is also influenced by 'network theorists' and shows governance in a more dynamic form (Coe and Hess, 2007).

Table 2.3: Different Forms of BSRs.

BSR Type	Characteristics
Hierarchy	- The complexity of the transaction is high, so it is difficult to codify the transaction information. - The complexity of the project can create difficulties in finding suppliers who are competent enough. - The need to exchange tacit knowledge and the limitations affecting suppliers drives the buyer to rely on in-house capabilities. Buyers also opt for this governance type if there is a need to control specific resources, such as intellectual property. - Production projects are explicitly coordinated; the lead firm has complete control over its in-house activities.
Captive	- The complexity of the transaction is high and so is the ability to codify the transaction information. - There is low supplier competence however, meaning that "a great deal of intervention and control" is required by the lead firm in order to cope with the complexity (Gereffi *et al.*, 2005:87). - The suppliers face high switching costs (because of the buyers' level of intervention and control), thus become transactionally dependent on the buyer. - Buyer exerts power over the supplier and explicitly coordinates its activities as the dominant party.
Relational	- The complexity of transactions is high and the ability to codify the transaction information is low. However, supplier capabilities are high, so buyers are still able to outsource (unlike with the hierarchical and captive type). - Complex, tacit information is exchanged through a close, two-way dialogue, as opposed to a "unidirectional flow of information and control" (Gereffi *et al.*, 2005:87). - Power is more evenly balanced, with a mutual dependence and high switching costs for both the buyer and supplier. - The relationship is more of a partnership, whereby the buyer and supplier rely on each other at different times and work together (commonly long-term) to "achieve mutual and individual goals" (Cannon and Perrault, 1999).
Modular	- The complexity of the transaction is high, with less standardised product specifications than market BSRs. However, the information can be codified and exchanged between buyers and external suppliers. - Unlike captive BSRs, supplier competence is also high, meaning suppliers are less dependent on the control/support of the buyer and their switching costs are low. - Suppliers typically follow a customer's set specifications. - The structure is very 'fluid' with both the suppliers and buyers working with multiple partners. - There are low levels of explicit coordination and power asymmetries.
Market	- The complexity of the transactions is low and product specifications

	are typically standardised, so the transaction information can be easily codified. - Suppliers have a high enough capability to deliver the product, with little coordination required from the buyer. - Power asymmetries are low, as both the buyers and suppliers work with multiple partners.

Source: Author. Based on Gereffi *et al.* (2005:87).

As stated above, the two extremes in the fivefold typology of BSRs are the market and hierarchy network forms. Market BSRs are arms-length with low asset specificity, whilst hierarchy BSR are in-house, tightly coordinated and non-standardised. This continuum is similar to typologies in the business management and marketing literature, which range from arm's length associations with discrete (i.e. one-time, competitive) exchanges, to coordinated partnerships with relational (i.e. long-term, cooperative) exchanges and closer ties (see Vesalainen and Kohtamaki, 2015; Helper and Sako, 1995; Wu and Choi, 2005). The closeness of ties refers to “the intensity and valence of prior interaction” (Wuyts and Geyskens, 2005:103).

The five types vary systematically according to whether they have high or low values of the following three factors:

(i) “the complexity of information and knowledge transfer required to sustain a particular transaction, particularly with respect to product and process specifications”;

(ii) “the extent to which this information and knowledge can be codified and, therefore, transmitted efficiently and without transaction-specific investment between the parties to the transaction”. Information is codified in the form of detailed instructions; and

(iii) “the capabilities of actual and potential suppliers in relation to the requirements of transaction" (Gereffi *et al.,* 2005:85).

For example, with market BSRs information is easily codified and suppliers have strong capabilities, so there is less need for explicit coordination and power asymmetry. Table 2.4 presents the high or low values of the five governance types.

Table 2.4: Characteristics of buyer-supplier relationships.

Factors	**BSR Type**				
	1. Market	**2. Modular**	**3. Relational**	**4. Captive**	**5. Hierarchy**
Complexity of transactions	Low	High	High	High	High
Ability to codify transactions	High	High	Low	High	Low
Capabilities in the supply-base	High	High	High	Low	Low

Source: Author. Based on Gereffi *et al.* (2005).

There are three additional combinations of the above factors which are not considered as BSR types. First, two combinations of “low complexity of transactions” and “low ability to codify” are excluded, as they are “unlikely to occur” (Gereffi *et al*., 2005:87). Second, if the “complexity of transaction is low and the ability to codify is high” then a supplier with low capability would be uncompetitive and excluded from the value chain. The three combinations of factors mentioned above are based on earlier empirical research. For example, Sturgeon and Lee (2001) and Sturgeon (2001) emphasised the influence of information complexity and asset specificity on supply relationships in the electronics industry, whilst Humphrey and Schmitz (2000, 2002) highlighted the impact of supplier competence (Gereffi *et al.*, 2005).

The five BSR governance types range from low (market) to high (hierarchy) levels of explicit coordination and power asymmetry (Figure 2.1).

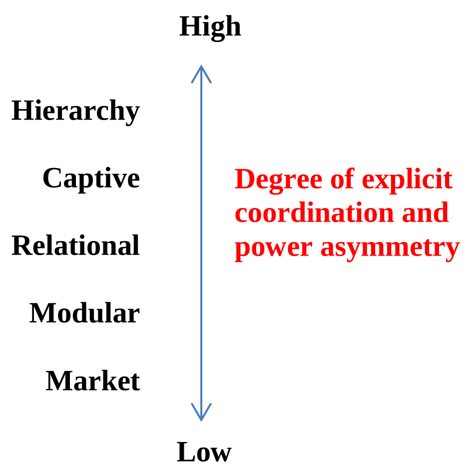

Figure 2.1 Degree of explicit coordination and power asymmetry for the five types.

Source: Author (Gereffi *et al.*, 2005).

Power relates to the degree to which a buyer or supplier may "influence the conduct" of the other (Tokatli, 2007:68). For example, 'lead' or 'co-ordinating firms' will: (i) set product specifications/schedules; (ii) control strategic functions; and (iii) allocate "where, when and by whom value is added" (Ponte and Sturgeon, 2014:201). It is a relational concept, since "the exercise of power by one party depends on the powerlessness of the other" (Tokatli, 2007:68). The level of corporate power is proportionate to the firms' "control of key resources (intellectual property assets, capital, innovativeness etc.) (Dicken *et al.*, 2001:93). Additionally, power is closely linked to dependence, where "the most independent partner dominates the exchange" (Caniëls and Gelderman, 2007:221). The level of dependence by one party on another and vice versa is a measure of the value they each attach to the relationship (Coe *et al*., 2008; Mulhall and Bryson, 2013; Martin-de-Castro, 2010:656). In captive BSRs, the buyer exerts power over the supplier and explicitly coordinates its activities as the dominant party (Gereffi *et al.,* 2005; Rutherford and Holmes, 2008). In contrast, in relational BSRs, power is more evenly balanced, with coordination "achieved through a close dialogue... as opposed to the more unidirectional flow of information and control" (Gereffi *et al*., 2005:87).

The GVC BSR governance typology has been "widely utilized and extensively cited", since it has three key characteristics which make it a useful tool for conceptualising the character and structure of BSRs (Gereffi, 2014:14). First, it effectively outlines the organisational structure and power dynamics of BSRs (Ponte and Sturgeon, 2014). Second, the typology categories are not oversimplified or too complex, but based on "the fewest number of dimensions that can explain variations" (Tangpong *et al.,* 2008:577). Finally, there are consistencies, between the variables and types in the GVC governance typology and alternative typologies in the business management and marketing literature. For example, the types exist consistently along continuums relating to power dynamics and levels of coordination (Vesalainen and Kohtamaki, 2015; Macneil, 1980; Helper and Sako, 1995; Wu and Choi, 2005; Cox *et al.,* 2001). Similarly, information exchange (Håkansson and Snehota, 1995), specificity of investment (Bensaou, 1999), forms of coordination (Duffy, 2008), dependency (Caniëls and Gelderman, 2007) and power (Cox *et al.,* 2001) are all reoccurring BSR variables found across the business management and marketing literatures.

Nevertheless, there are limits to the GVC typology, since it was intended only as a "simple framework" for isolating key variables and patterns of "value chain governance" (Gereffi *et al.*, 2005:82). Consequently, Coe and Hess (2007) argue that the fivefold typology is still not complex enough to account for the different network configurations across different industries. For example, there are industry specific features which may have been overlooked and need to be considered. These industry-specific features may have been ignored because, apart from electronics, the industries on which Gereffi *et al.* (2005) based the typology on are low-tech (i.e. bicycle, apparel, horticultural). This means that factors such as technological lock-in will not have influenced the operationalisation of the types, despite influencing BSRs in high-tech industries. This thesis develops the typology in a way that considers the specific features of the *space* sector.

Additionally, existing empirical applications of the GVC governance typology have focussed on a typical set of BSRs between a lead firm of a value chain and its first-tier supplier(s) (Gibbon *et al.,* 2008). However, in production there is often more than one lead firm and procurement moment (Ponte and Sturgeon, 2014:206). Therefore, this research contributes towards development of the literature by applying the typology to a series of linked satellite production projects (with varying lead firms). This allows a comparison of BSRs at different stages of a satellite mission, which is a valuable contribution since the GVC literature is yet to distinguish between the BSRs at a single procurement moment and 'overall governance' of a series of linked production projects (Ponte *et al.,* 2008:7).

Furthermore, the GVC governance literature has focussed on "the top-down process" of buyers coordinating their suppliers (Lee and Gereffi, 2015:321). However, this is not representative of the significant role that suppliers can play in shaping their own BSRs, as independent partners (Caniëls and Gelderman, 2007; Blazek, 2015). Rosell *et al.* (2014:2) for example, argues that suppliers are increasingly "acting as production partners", as they contribute to the product development processes of their buyers. Similarly, Ponte and Sturgeon (2014:205) point to “the possible role of powerful component suppliers”. This thesis aims to further develop this argument by developing the evidence of supplier power in the UK *space* sector and distinguishing between captive-buyer and captive-supplier type BSRs. Bensaou (1999) made the distinction between captive-buyers and captive-suppliers in the business management literature, by comparing their market characteristics (Table 2.5).

Table 2.5: Characteristics of Captive Types.

Type	**Characteristics**
Captive-supplier	- The complexity of the transaction is high and so is the ability to codify the transaction information. - The supplier faces high switching costs, and thus become transactionally dependent on the buyer. The supplier has low bargaining power despite holding proprietary information. - The buyer exerts power over the supplier and explicitly coordinates its activities as the dominant party. - - The market has “high growth” with “fierce competition” (Bensaou, 1999:38).
Captive-buyer	- The complexity of the transaction is high and so is the ability to codify the transaction information. - There is a “concentrated market with few established players”, thus the buyer becomes transactionally dependent on the supplier (Bensaou, 1999:38). - There is stable demand, limited market growth and the supplier holds proprietary information. Therefore, the supplier has strong bargaining power over the buyer.

Source: Author (Gereffi *et al.*, 2005; Bensaou, 1999:38).

The profile of a captive-supplier type is closest to that of Gereffi *et al.*’s (2005) captive type, where the buyer holds power over the supplier as the dominant party. The absence of a captive-buyer type in the GVC BSR governance typology is a consequence of its “narrow” focus on the BSRs between lead firms and their immediate supplier(s) (Rainnie *et al.*, 2011:158). However, this research has a broader focus on a series of BSRs, which vary in their market characteristics.

The ‘ability to codify information’ and ‘supplier capability’ have also been criticised as being subjective variables in the GVC typology (Gibbon *et al.*, 2008:8). This subjectivity is a result of the lack of a clear definition of what constitutes as a necessary ability to codify information and sufficient supplier capability (Gereffi *et al.*, 2005). This lack of clarity means that this research places greater importance on other variables in the typology, for example degree of explicit coordination and power asymmetry.

This shift in focus away from the ability to codify and supplier capability as variables affects the operationalisation of the BSR types. For example, to Gereffi *et al.* (2005), the key difference between captive and relational BSRs is that the captive type has a high ability to codify information but low supplier capability, whilst the relational type has a low ability to codify information but high supplier capability. However, if greater importance is placed on coordination and power asymmetry, then the distinction would be that a captive type has one-sided coordination and power, whilst a relational type has even power distribution and a low degree of explicit coordination. For example, to Gereffi *et al.* (2005), the BSRs governing the sale of a satellite would be relational because the complexity of the transaction is so high that it is difficult to codify the information and it demands high supplier capability. However, if closer attention is paid to coordination and power asymmetry, then one could argue that if the BSRs have one-sided coordination and power then they are more of a captive type BSR. This highlights how, depending on which typology variable is focussed upon, characteristics of different types of BSRs can overlap, with the potential for the types to evolve into one another over time (Lager and Rennard, 2014; Coe and Hess, 2007). For example, a captive exchange can develop into a relational one as power becomes more evenly balanced. Consequently, BSRs are not fixed, but can shift in nature over time. Therefore, time is a variable that impacts on BSRs; this is something which Gereffi *et al.* (2005) did not highlight, but is explored in this thesis.

Another criticism of the GVC governance typology is that it does not fully consider the impact of external governance factors (such as regulations) on BSRs (Gibbon *et al.,* 2008; Rainnie *et al.,* 2011). Gereffi *et al*. (2005:99) does acknowledge that regulations are the "rules of the game" and "have a profound effect on the shape and direction of change in global value chains". However, there has been little development on what form this effect may take. This thesis accounts for this by investigating the impact of external governance factors on the competitiveness and organisation of UK satellite firms. This contributes to moving towards a 'synergistic governance' theory, which blends theoretical elements from the micro (private) and macro (public governance) level of analysis (Gereffi, 2014:1).

2.4.3 The Organisation of Production in the UK *Space* Sector

A review of the literature on the organisation of production found that research on an industry's organisation would complement a study of its firm-level competitiveness (Walker, 2000; Lane and Probert, 2004). The literature was found to be divided in two parts: (i) the distribution of production tasks; and (ii) the nature and extent of relationships with buyers/suppliers.

The review identified that there is a rich literature exploring the distribution of production tasks, which offers competing approaches for analysing how production is organised. These include the GCC, GVC and GPN approaches. Nevertheless, it was apparent that a PPT approach would be most appropriate to apply to research on the *space* sector, since it avoids the 'overused' network term, encourages a more balanced understanding of different network scales and considers service functions (Bryson, 2008). The PPT approach is combined with the netchain and texture models, to ensure that links between production projects and the projects' contextual framework are considered.

Furthermore, the GVC governance typology developed by Gereffi *et al*. (2005) is used as a valuable tool to conceptualise the structure and character of BSRs in the UK *space* sector. This typology was chosen because it: (i) effectively highlights organisational structure and power dynamics of BSRs; (ii) is an accessible but not oversimplified tool; and (iii) has previously proven relevant to a range of empirical contexts (Gereffi *et al.*, 2005; Ponte and Sturgeon, 2014; Saccani *et al*., 2014). However, there are also criticisms of the typology, including that industry specific features are ignored and need to be accounted for (Gibbon *et al.*, 2008; Yang and Coe, 2009; Rainnie *et al*., 2011). Through identifying these shortcomings, the typology and GVC governance literature are developed further.

The nature and extent of BSRs is part of the private governance of the industry. The next section explores the broader governance literature. This integration of theories on organisation and governance is important to ensure that relational economic geography does not continue to "ignore the insights of a sizeable institutionalist literature" (Jones, 2014:608).

2.5 Governance

The term governance "stems from the Greek *kybernan* meaning to pilot, steer or direct" (Levi-Faur, 2012:5), yet the term is subject to multiple definitions and a varied use across different literatures (Richardson, 2012; Reed and Bruyneel, 2010; Stone, 2013; Lewis *et al.*, 2002). This is true of the geographical literature, since different "theoretical points of entry" alter the "sphere of governance" focussed on and thus the definition of governance (Lewis *et al.*, 2002:433). For example, economic geography defines governance as "the framework and institutional structures by which rules are set and implemented" (Nadvi, 2008:324). This definition has developed from a firm-level point of entry and a focus on the 'external architecture' of institutional arrangements within which production is embedded (Neilson and Pritchard, 2009: 9). This concept of 'embeddedness' is central to economic geography thought and the acknowledgement of the significance of institutions is an example of the 'institutional turn in social science' (Jones, 2008).

In contrast, political geographers centre their governance research on the 'hollowing out' of the "nation state's powers and responsibilities" (Prince, 2012:188). Consequently, the political geography literature defines governance as a new process of governing, signifying change from the "formal, centralized and vertical exercise of power" associated with government (Harrington *et al.*, 2008:200). Governance is at play when there is a democratic involvement of other societal actors in policy decisions (Rothsetin, 2012; Loorbach, 2010), and the sharing of "nation state's powers and responsibilities" with supranational and local institutions (Prince, 2012:188). This applies to the *space* sector because firms are impacted by governance across national, regional and global scales (Brenner, 2001).

The existing conceptual toolkits (Gereffi *et al.*, 2005) in economic geography for understanding firm-level governance have been criticised for being too descriptive and underestimating how governance structures evolve over time (Coe and Hess, 2007; Ponte and Sturgeon, 2014; Smith, 2015:296; Thomsen 2015:2). Similarly, the geopolitical literature on governance has been criticised for ignoring the firm-level impacts of governance (Prince, 2012). This suggests that blending the economic and political points of entry on governance research would be a profitable engagement, as each could address the research gaps in the other. For instance, whilst the political approach would benefit from considering the implications of governance at the firm-level, the economic approach would profit from understanding how governance structures evolve over time. Consequently, a blended approach of both points of entry are applied to this research, to deliver a "meaningful understanding" of an "industry and its governance" (Lewis *et al*., 2002:433).

In order to distinguish between various spheres (i.e. form and scale) of governance it is helpful to categorise them (Nadvi, 2008:324). For example, Gereffi and Mayer (2006) distinguish between: (i) market governance - the institutional frameworks which regulate markets; (ii) corporate governance – the accountability of firms to their stakeholders; and (iii) industrial governance - the organisation of and relationships between supply chain actors. Coe and Hess (2007) also categorise industrial governance, but instead refer to it as 'inter-firm' governance and separate it from 'intra-firm governance' (the internal organisation of the firm). In contrast, Mayer and Pickles (2010:2) separate 'public governance' (imposed by the state) and 'private governance' (imposed by other actors). This relatively simple typology is effective and appropriate to apply to this study, as it explores the impact of a range of governing actors on the *space* sector. Consequently, the remainder of this sub-section separates public and private governance forms, dealing with each of them in turn.

2.5.1 Public Governance

Public governance is a "system of rules" or "mechanism of decision making" imposed by the state (Rosenau, 1995:13; Levi-Faur, 2012:9). There are a number of 'apparatus' of public governance which apply to different contexts (Lewis *et al.*, 2002:454). For example, in the context of industry competitiveness and the organisation of production, industrial policies are utilised in and aimed at industry development (Motoyame *et al.*, 2011; Rodrik, 2004). Public governance, acting through industrial policies, can be separated into two categories: (i) facilitative governance; and (ii) regulatory governance (Mayer and Pickles, 2010:2).

Facilitative governance focusses on promoting economic activity, such as enabling market creation and attracting investment (Mayer and Pickles, 2010:2). A common approach to this is providing financial support, including: (i) grants for private companies; (ii) tax incentives; (iii) tax credits for research and development; and (iv) grants and provision of land for improvements to infrastructure (Hanson and Rohlin, 2011; Holmes, 1998:672; Schacht, 2010; Buss, 2001). Financial support is justified on the basis of "future tax payments" and the "expectation of a reasonable rate of return" (Hanson and Rohlin, 2011:427; Salamon, 1977:1029). It is significant because it reduces the barriers to entry for firms by alleviating some of the costs, which is particularly valuable for capital-intensive manufacturing firms (Brown *et al.*, 2013; Holmes, 1998). Other examples of facilitative governance include skills development and investment in training services and education (Arvanitis *et al.*, 2002). This skills development and training helps to address any imbalances between the availability of human capital and workforce demand and is identified as a 'redistributive' form of facilitative governance (McCann and Ortega-Argiles, 2013; Gertler, 2003; Christopherson and Clark, 2007). In addition, 'public-private partnerships' (PPPs) are an example of facilitative governance (Palmer, 2013; Mayntz, 2002). PPPs are "a rubric for describing cooperative ventures between the state and private business" (Linder, 1999: 35). They are not just about promoting economic activity, as in many cases PPPs will be the only means through which a service can be delivered effectively or even at all (Boycko *et al.*, 1996; Palmer, 2013).

Regulatory governance relates to the constraint of the behaviour of firms through regulations. Mayer and Pickles (2010:2) used the example of regulations which restrict the exploitation of workers; however, it could apply to any behaviour. To Dicken (1992:304), there are three key types of regulation. First, trade regulations or those which govern access to markets. Trade regulations extend over national borders and are significant because they dictate whether firms are "able to engage with global markets", influencing the geography of their production (Neilson *et al.*, 2014:3). Second, there are regulations "relating to inward foreign direct investment", which concern "access and rules of operation" (Dicken, 1992:304). Finally, there are regulations which relate to specific industry policies, aimed at regulating and/or stimulating industrial activity, which overlaps with facilitative forms of governance. For example, 'Good Manufacturing Practice' is a European regulation, which "ensures that products are consistently produced and controlled to the quality standards appropriate" (Plumb, 2005: 731).

Regulations are 'place-specific' and vary between different national economies (Lewis, 2002:439). This theory is consistent with the 'varieties of capitalism' and 'variegated capitalism' literature (Dixon, 2011; Peck and Theodore, 2007; Boyer, 2005; Dicken, 2001), which argues that national economies have remained distinct "in the face of globalization" (Lewis, 2002:439). The early foundations of the varieties of capitalism work lay with Shonfield (1965), who "presented vividly contrasting images of the British and French political economies" (Maloney and McLaughlin, 2005:5). Hall and Soskice (2001) then developed a distinction between 'coordinated market economies' (CME/American) and 'liberal market economies' (LME/Euro-Japanese). Variegated capitalism is the 'economic geography response' to varieties of capitalism, focussed on exploring "relations at scales other than the national" and transcending exaggerated geographical differences (Peck and Theodore, 2007:761). For example, Daniels *et al.* (2011:158) highlighted "the diversity of national economies that exist within the EU". Birsch *et al.* (2010:37) claimed that rather than being one or the other, these economies are often situated "on a continuum between coordinated-market economies and liberal-market economies". Institutional differences are relevant to this study because in the face of increasing global competition, a favourable governance system could generate a competitive advantage (Griffiths and Zammuto, 2005). Additionally, production networks are likely to cross a "multitude of institutional spheres", thus it is important to outline the impact of institutional differences (Dixon, 2011:194).

The political economy literature argues that facilitative and regulatory forms of public governance are significant because they play an "important role in fostering the competitive capabilities of industries and firms" (Griffiths and Zammuto, 2005:824). This concept of "institutional frameworks" shaping economic processes is referred to as 'institutionalism' (Cumbers *et al.*, 2003:327). Additionally, facilitative governance can have a strong influence over the organisation of production, since firms co-ordinate their production in ways "for which there exists institutional support" (Lane and Probert, 2004:249). For instance, firms locate their production activities in regions or nations which offer facilitative support. Similarly, firms base their location decisions on regulatory regimes (Coe *et al.*, 2008). Clark and Monk (2014) refer to these regulatory based location decisions as 'jurisdiction selection'. To Potts (2015:523), the best-known form of jurisdiction selection is "increasing profits by exporting activities to strategic locations around the globe". However, jurisdiction selection can also be applied to other examples. For instance, environmental regulations influence new plant location decisions of multinational corporations (List and Co, 2000, Jeppessen *et al.*, 2002; Kheder and Zugravu, 2012). For example, car manufacturing firms have been found to locate "pollution intensive plants" in "countries with less stringent environmental regulations" (List and McHone, 2000:177; McConnel and Schwab, 1990). These interactions between public governance and organisation of production/competitiveness highlight the importance of researching all three areas (governance, organisation and competitiveness) in this study. To Jones (2014:608) theories on organisation and governance must be better integrated, to ensure that relational economic geography does not continue to "ignore the insights of a sizeable institutionalist literature".

This sub-section has highlighted the impact of public governance on firm-level competitiveness and the organisation of production. Nevertheless, the impact of policy action or inaction is "rarely placed in the foreground" of relational economic geography research and "explicit theorization of the state's role (in production) has been somewhat lacking" (Neilson *et al.*, 2014:3; Smith, 2015:291). Consequently, Boschma and Frenken (2009:151) argue that institutional frameworks deserve "more explicit attention". This research seeks to address these research gaps through exploring the governance of the UK *space* sector. In addition, other industry studies have failed to differentiate between facilitative and regulatory forms of governance (see Bailey and Maresh, 2009; Bennett, 2000; Eling, and Marek, 2014; Griffin, 2008; McLaughlin and Maloney, 1999). This thesis makes this distinction and addresses the balance between the two forms of governance.

2.5.2 Private Governance

Public governance is not the only mechanism of control "over public sector activities", since non-state actors increasingly exercise control over firms (Scott, 2002:71). Consequently, research must also recognise the impact of private governance (Smith, 2015; Scott, 2002; Bennet, 2000). Private governance involves a "system of rules" or "mechanism of decision making" imposed by actors other than the state (Rosenau, 1995:13; Levi-Faur, 2012:9). To Nadvi (2008:324), these actors include businesses, non-government organisations (NGOs), trade associations and labour organisations, who define "many of the 'rules' through which global production networks are organised". However, to Sturgeon (2001:10) and Henderson *et al.*, (2002), NGO's and labour organisations are considered as part of "societal governance", whereas private governance involves only businesses. The control exercised by businesses primarily relates to the power exercised by the lead firms. This overlaps with the organisation literature on the GVC governance framework and types of BSRs (discussed in section 2.4.4).

There are other businesses which have control over production, yet have been overlooked by the private governance literature. These private actors can either be 'profit' or 'non-profit' and "influence state centric processes of regime-building" (Falkner, 2003:76). Examples include: (i) authorities who issue certifications and standards, such as The Forest Stewardship Council (FSC) and the International Accounting Standards Board (IASB); (ii) private environmental activist groups; (iii) social lobbying groups; (iv) trade associations; and (v) codes of conduct set by corporations (Gulbrandsen, 2004; Pattberg, 2005; Brammer *et al*., 2012; Mayer and Gereffi, 2010; Mattli and Buthe, 2005).

Insurance companies are also private governance actors. To Ericson (2000:532), private insurance is a "central institution of governance beyond the state", since insurance companies have the capacity to "set standards" (in respect of risk) and "enforce compliance" (via payment and premium levels) (Scott, 2002:65). Based on research on the maritime sector, insurers are also incentivised to help "manage risk", since "they bear the financial consequences" of any losses they insure against (Bennet, 2000:880). Consequently, insurers often become actively involved in procurement decisions. Bennet (2000:87) and Freeman and Kunreuther (1997:102) add that where insurance is compulsory, the insurer also adopts the role of an "enforcer" and become, in effect, a "watchdog over its customers rather than a service provider". Insurers base their decision on whether to insure a company on a range of factors, including financial responsibility, where the firm "must have access to enough capital to meet a specified level of liability" (Bennet, 2000:884). This thesis considers the impact of private insurers on UK satellite companies, addressing the gap in the literature where "lower-level decisions" made by "non-state organisations" have been neglected from studies on "contemporary governance arrangements" (Scott, 2002:56). The research also furthers the political-economic debate concerning the question of whether private governance actors cause a "growing constraint on governmental activities both nationally and internationally" (Scott, 2002:76).

There are competing theoretical models for analysing the "system of rules" or "mechanism of decision making" imposed by political bodies or private actors (Rosenau, 1995:13; Levi-Faur, 2012:9). Section 2.5.3 explores these models and identifies the approach that best applies to this study.

2.5.3 Competing Models for Analysing Governance

The three main approaches or models for analysing governance are: (i) state-centric; (ii) multi-level governance; and (iii) network polity. This sub-section explores which of the three approaches is most appropriate for analysing the governance of the UK *space* sector. A state-centric approach focusses its territorial analysis on the nation state, at the expense of subnational and supranational features (Jessop, 2004). This involves analysis of state power, with a focus on “the state’s basic structure, institutional architecture, and specific organisational forms” (Jessop, 2004:50). However, this approach ignores the recent trend of the “de-statisation of the political system”, where there has been a shift of power from state governments to multiple territorial scales (Jessop, 2004:14). For example, national public institutions are not solely responsible for public governance, since they commonly operate within “global public policy networks” and are influenced by the sharing of problems, policy ideas and partnerships with other actors (Stone, 2013:5). Additionally, there are supranational governing bodies with power (Stone, 2013; Loorbach, 2010; Zurn, 2012). Consequently, industries are steered by various agencies, institutions and systems on the subnational, national and supranational scale. To Brenner (2001:604), these scales are “crucially important dimensions of geographical differentiation”, thus it is important that the governance analysis identifies any variations between actors.

To acknowledge these variations and the “horizontally decentralised” power or authority over firms, a multi-level governance perspective would perhaps be more appropriate to apply to this research (Harrington *et al.*, 2008:200). A multi-level governance perspective would be better suited because it is not restricted to the national scale, but instead explores “multiple sites and scales of governance” and the power differences between them (Bulkeley and Betsill, 2005:43). For instance, it identifies ‘dominant scales’, which exercise power over other organisations at different scales and 'nodal scales', which are non-dominant but still make an important contribution to the industry's governance in delivering certain activities (Collinge, 1999; Jessop, 2005). The multi-level approach also explores challenges associated with decision-making on the supranational scale. Stone (2013:25-27) observed for example, that global institutions often struggle without a "sovereign decision maker" and the "means to enforce policy compliance". The multi-level approach further explores how challenging it is to secure international treaties and conventions when there are a number of parties involved (Stone, 2013). There are also issues concerning global governance "increasingly undermining the regulatory powers of national governance" (Nadvi, 2008:331). In line with this literature, the research considers the impact of global institutions alongside the nation state and explores the relationship between the two (Little *et al.*, 2012).

To Hooghe and Marks (2001), there are two strands to the multilevel governance approach, which treat the distribution of power between these scales differently. First, there is a 'hierarchical' strand which focusses on "power sharing among a limited number of governments operating at just a few levels" (Hooghe and Marks, 2001:6). This is appropriate where "a clear hierarchy between distinct tiers of governance exists" (Bulkeley and Betsill, 2005:36). Second, there is a 'polycentric' or 'multi-centric' strand which focusses on "multiple overlapping and interconnected horizontal spheres of authority", where power is more evenly dispersed across a network of governance actors (Hooghe and Marks, 2001:6). To Ansell (2000:306), in the polycentric approach horizontal relationships are as important as vertical relationships and "the central actor behaves more as a 'gateway' (or liaison) than a gatekeeper". This is favoured over the hierarchy approach, as often different sites and scales of governance cannot be "nested in a neat hierarchy" but instead "coexist and interpenetrate in tangled and confused ways" (Jessop, 2004:227). The multilevel governance therefore, is described as 'heterarchial' rather than hierarchical, since there are lateral links between governance organisations and "lower-level units" have relationships with "higher-level centres" (Ansell, 2000:306). To Kontopoulos (2006), a heterarchy is distinguished as entailing 'many to many' relationships between different nodal scales, as opposed to 'one to many' relationships in a hierarchy structure.

The polycentric strand is so different to the hierarchical perspective (most commonly associated with multi-level governance) that it has developed into a parallel body of work (identified as the 'network polity' approach). The polycentric strand is applied to this thesis. To Coen and Thatcher (2008:50), there are three key aspects to this network polity approach: i) the linkages between both public and private governance actors across different scales; ii) power shifts from "previously well-established levels to organisations or individuals whose main roles are linking and co-ordinating actors"; and iii) any changes from a hierarchical form of governance to a network form. The linkages and interactions between different governance actors are interesting and are emphasised in this research. To Kooiman (2000:218), there is an "enormous variety of interactions" (i.e. formal, spontaneous, horizontal and vertical) and mutuality (two-sided) is a central aspect. One form of interaction that is identified in this thesis is 'metagovernance'. To Jessop (2011:9), metagovernance "refers to the governance of governance" and occurs when:

> "…states at different levels provide the ground rules for governance and the regulatory order in and through which governance partners can pursue their aims…" (Jessop, 2011:119).

By way of illustration, national governments may control what "powers or competencies go up, down, or sideways" (Jessop, 2004:14). Metagovernance is important to include within a governance analysis because it accounts for the “input side of policy formation” and the construction of governance forms (Jessop, 2011:9; Dunsire, 1993).

To conclude, out of the competing theoretical approaches, the polycentric strand is the most appropriate for theoretically framing this governance research, since it is best suited to the multi-scalar and multi-centric governance that impacts upon the *space* sector. Therefore, this thesis explores different sites of governance across four scales (global, European, national and industry-level), and the vertical and horizontal interactions between those scales. This exploration includes identifying examples of metagovernance.

2.5.4 The Governance of the UK *Space* Sector

This section has highlighted the different ways in which the multiple actors in a society may contribute towards the governance of an industry (Lobel, 2012). Consequently, a conceptual framework which blends economic and political geography theories would be most appropriate to apply to this research, as it would consider a range of governing actors on different spatial scales (Lewis *et al.*, 2002; Prince, 2012; Nadvi, 2008; Neilson and Pritchard, 2009). These governing actors include the state, which impacts on firm-level competitiveness through various policies and regulation (Griffiths and Zammuto, 2005).

Actors other than the state also exercise control (Scott, 2002; Smith, 2015; Bennet, 2000; Rosenau, 1995; Levi-Faur, 2012; Mayer and Pickles, 2010; Nadvi, 2008). These actors include private insurers, whose influence has been overlooked by the private governance literature. In response to this, this research outlines how insurance companies “set standards”, “enforce compliance” and “manage risk” in the UK *space* sector (Scott, 2002:65; Bennet, 2000:880). This furthers the political-economic debate on whether private governance actors cause a “growing constraint on governmental activities both nationally and internationally" (Scott, 2002:76). A polycentric approach theoretically frames the analysis of the public and private forms of governance, since it is best suited for identifying the multi-scalar actors who govern the UK *space* sector (Coen and Thatcher, 2008; Kooiman, 2000). This involves identifying interactions between the different scales of governance, including metagovernance (Jessop, 2011; Jessop, 2004; Dunsire, 1993).

The next section outlines how the governance, organisation and competitiveness literature can be brought together to form a single conceptual framework and is applied to this research.

2.6 Conceptual Framework

The conceptual framework for this research (Figure 2.2) is based on the relationship between competitiveness, organisation and governance. The framework blends firm-level concepts on competitiveness (Barney, 1991; De Rassenfosse, 2012; Martin and Sunley, 2006; Phelps and Fuller, 2016), organisation (Gereffi *et al*., 2005; Smith, 1776; Harvey, 2014; Neilson *et al*., 2014) and governance (Jessop, 2011; Coen and Thatcher, 2008; Nadvi, 2008; Kooiman, 2000) literatures, providing an integrated way of thinking about how products and services are produced. This integrated approach is important for developing general understanding on a critical sector which has been overlooked by the economic geography literature. Each element will now be explained in turn. The remainder of the section will also identify where the various elements are applied in the thesis.

The approach to understanding organisation is to identify a series of production projects (PPT approach) (Bryson, 2008), explore the links between them (netchain literature) (Coe *et al*., 2008; Lazzarini *et al*., 2001), and outline when and how they are influenced by the industry's contextual framework (texture approach) (Fineman and Hosking, 1990; Cooper and Fox, 1990) (Section 2.4.1). The production projects are interdependent, since the output of one is the input of another and there are two-way feedback loops between them (Coe *et al*., 2008:275; Lazzarini *et al*., 2001). These links between the productions projects are governed by BSRs and the nature and extent of these relationships or their 'type' are explored in Chapter 6. Each production project is managed by a lead firm or 'prime' (in the case of manufacturing), which requires a set of tasks, resources and routines. The firm will either choose to vertically integrate all of the production tasks or subcontract some out externally. Outsourced tasks are linked by BSRs and managed by 'secondary lead firms', which require their own resources and routines, and lead to further tasks. The secondary lead firms will outsource some of these tasks, where necessary. The firms involved with these production projects are identified and characterised in Chapter 4.

The completion of the tasks and the overall production project is dependent on firms having access, to or developing, internal resources (Barney, 1991; Peteraf, 1993). These resources provide a source of competitiveness that differentiates firms from their competitors (RBV). They are developed, accessed or performed through evolutionary routines that may evolve over time (evolutionary approach) (Bryson and Ronayne, 2014; Phelps and Fuller, 2016). Identifying these routines and the internal resources is the focus of Chapter 7. Understanding the overall competitiveness of the sector would require consideration of all three linked production projects.

The organisation of the tasks/projects and the competitiveness of the firms are influenced by external factors, particularly governance. There is governance of the overall *space* sector, the production projects and individual tasks. The governance actors may be private or public and exercise control on a firm, national or supranational scale (Mayer and

Pickles, 2010; Smith, 2015; Scott, 2002; Hooghe and Marks, 2001). Furthermore, the forms of governance may be regulatory or facilitative; their impact on different stages of UK satellite production projects will be discussed in Chapter 5. The consideration of governance as part of the contextual framework is reflective of applying the texture model to strengthen the adopted PPT approach (Cooper and Fox, 1990: Bryson, 2009).

The overall aim of the conceptual framework is to provide a holistic understanding of the UK *space* sector. It achieves this through integrating theories on competitiveness, organisation and governance, and looking at the industry at a whole series of scales, namely: (i) sector; (ii) production project, (iii) firm; and (iv) production task. A variant of the conceptual framework is provided in Chapter 8, with additions made to reflect the research findings.

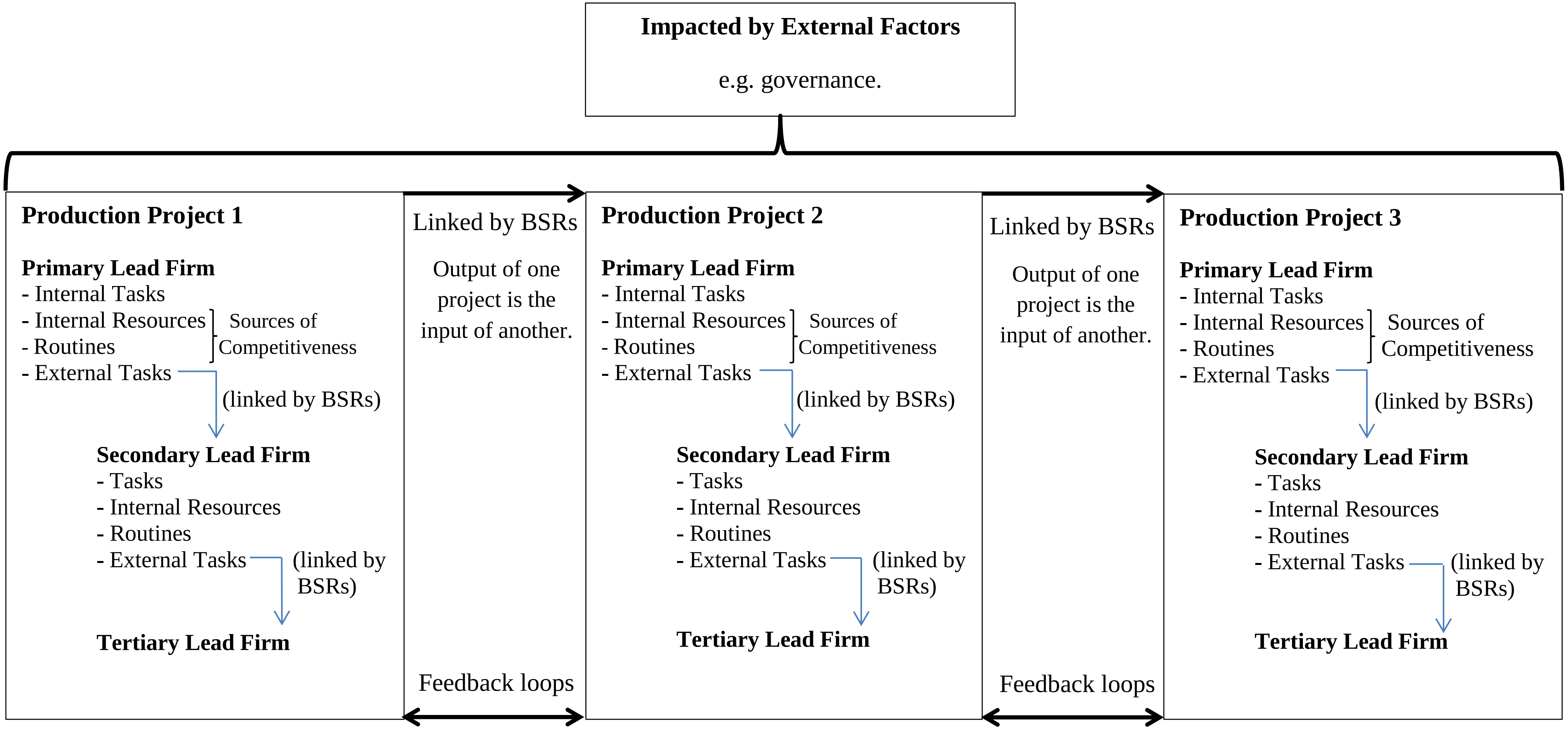

Figure 2.2: Conceptual framework for understanding firm and sector competitiveness. **Note**: BSRs are 'Buyer-Supplier Relationships'

Source: Author.

2.7 Concluding Remarks

This chapter has highlighted the extent to which existing studies have conceptualised *space* as though it is isolated from the economy, without due consideration of the industry driving the use of *space* and the impacts of that industry on the ground. In order to understand the grounded nature of *space*, there is a need for research on the competitiveness, organisation and governance of the satellite industry. This chapter has examined the literature on those three areas of research, highlighting any research gaps or limitations in respect of current understanding. This section brings together any related ideas and outlines the research questions.

First, the chapter identified theoretical perspectives which approach understanding firm-level competitiveness in different ways (Taylor and Asheim, 2001; 316; Phelps and Fuller, 2016). This study intends to explore a range of competing explanations to provide a holistic understanding of a sector which has previously been ignored by the economic geography literature. Therefore, the appropriate approach is to apply theory from both the RBV and evolutionary perspective. It is possible to blend these theories since the scales of analysis for both are on the firm-level and their arguments do not conflict. The research identifies the internal resources that are a source of competitiveness for UK satellite companies, whist highlighting the routines which develop or access these resources. To O'Regan, and Sims (2008:410), the sources of firm competitiveness are often "multifactorial" and "cannot be attributed to only one resource". Therefore, the research investigates the competitive advantages created by multiple intangible resources. The research also examines how, and the extent to which, orbital slots and frequency spectrum create competitive advantages. This contributes to the vertical geopolitics work, which explores the 'height and depth' of territories (Weizman, 2002: 3; Elden, 2013:49).

Firm-level competitiveness is influenced by the organisation of production. For instance, a firm's decision about whether to distribute its activities is part of its competitive strategy and the character of its BSRs is an external factor influencing its competitiveness. Therefore, the organisation literature was also reviewed in this chapter, including that which focusses on the distribution of production and how constellations of economic actors are organised (Luthi *et al.*, 2010). This literature, from relational economic geography, management and organisation studies, has identified several competing approaches for understanding the organisation of production. However, the PPT approach was found to be most appropriate to apply to this research, since it considers both manufacturing and service functions, which are both involved in satellite production projects (Bryson, 2009:37). The consideration of service functions is significant, since despite the 'range of service functions' involved in modern production, the GVC and GPN literature has often ignored service tasks (Coe *et al.*, 2008; Walker, 2000). Additionally, academics and policy makers lack a 'cross-functional perspective', as they often discuss manufacturing and service tasks independently (Ernst and Kim, 2001; Henderson *et al.*, 2002; Slepniov *et al.*, 2014). However, the PPT approach is subject to limitations. For instance, although the "various forms of backward and forward linkages" within a production project are explored, the interactions between production projects and how they may be interdependent are not (Bryson, 2009:42). This limitation is important to address, since the output of one production project is often the input of another. Additionally, the PPT approach does not consider the impact of the contextual framework on production projects. The contextual framework includes external factors which influence firm-level competitiveness. Consequently, the approach to this research combines the PPT framework with insight from the netchain (Coe *et al*., 2008; Lazzarini *et al*., 2001) and texture literature (Cooper and Fox, 1990).

Literature on the nature and extent of BSRs (known as ‘industrial governance’) also contributes towards understanding on the organisation of production and was therefore part of the literature review (Henderson *et al.*, 2002; Gereffi *et al.*, 2005; Coe *et al.*, 2008; Hughes *et al.*, 2008). The chapter identified that a common approach to framing an analysis of BSRs is the use of a typology, since it considers “a variety of different relationship characteristics” simultaneously (Cannon and Perrault, 1999:440). Consequently, the GVC governance typology developed by Gereffi *et al*. (2005) is applied to this research to conceptualise the structure and character of BSRs in the UK *space* sector. This typology was chosen because it: (i) effectively highlights organisational structure and power dynamics of BSRs; (ii) is an accessible but not oversimplified tool; and (iii) is consistent with other typologies (Gereffi *et al.*, 2005; Ponte and Sturgeon, 2014; Saccani *et al*., 2014). However, there are also criticisms of the typology, including that industry specific features are ignored and instead need to be accounted for (Gibbon *et al*., 2008; Yang and Coe, 2009; Rainnie *et al*., 2011). The thesis will address these criticisms and in doing so further develop the typology and GVC governance literature.

Firm-level competitiveness is also influenced by external factors, such as governance. For example, regulatory governance influences the “nature of competition”, whilst facilitative governance can provide solutions to overcoming negative lock-in (Nachum, 1998:465). Consequently, research on the governance of the *space* sector forms a core part of the thesis and thus, literature on different forms and scales of governance was also reviewed in this chapter. Based on the review, the approach to the governance aspect of the research is a blend of economic and political geography theories, as this ensures that a range of governing actors at different spatial scales would be considered (Lewis *et al.,* 2002; Prince, 2012; Nadvi, 2008; Neilson and Pritchard, 2009). The outcome of this blend is a polycentric approach, which explores both public and private forms of governance at the industry, national and supranational level (Coen and Thatcher, 2008; Kooiman, 2000). This addresses the gap in the relational economic geography literature where the impact of policy action or inaction has “rarely” been “placed in the foreground” (Neilson *et al.*, 2014:3). In addition, the chapter identified that outlining the role of private insurers in the sector would further the political-economic debate on whether private governance actors cause a “growing constraint on governmental activities” (Scott, 2002:76). Furthermore, it highlighted the value in identifying whether the forms of public governance impacting on the UK *space* sector are ‘place-specific’ (Smith, 2015; Lewis, 2002; Peck and Theodore, 2007; Dicken, 2001).

At the end of Chapter 1, two research aims and four objectives were outlined. In line with those objectives and the research gaps identified in this section, this thesis addresses the following research questions:

Research Questions:

1. How are production projects and tasks distributed in the *space* sector, including their spatial configurations, and what actors are involved at which stage of production?
2. What are the key sources of competitiveness for UK satellite companies, taking in account intangible and tangible resources, as well as external factors?

3. What is the ‘nature and extent’ of the relationships between buyers and suppliers involved in the production of UK satellite infrastructure and services?
4. What is the impact of national and supranational forms of public and private governance on different stages of UK satellite production projects?

The conceptual framework (Figure 2.2) was applied to address these research questions and paired with an appropriate research design, approach and methods. The chosen design, approach and methods are outlined in the next chapter.

CHAPTER 3

RESEARCH DESIGN, APPROACH AND METHODS

3.1 Introduction

The spatial configurations of satellite firms, and the "interactions between the multifarious sets of actors, agents and institutions" involved, have been overlooked in the academic literature (Dicken, 2006:14; MacDonald, 2007:603). To address this 'silence' in the economic geography literature, this thesis aims to explore the competitiveness, organisation and governance of the UK *space* sector (Dicken, 2006). This chapter outlines the design, approach and methods adopted for this research.

The structure of the chapter is separated into five sections. First, the approach to the research and the underlying theoretical assumption are outlined (Bryman, 2012). Then, the four stages of data collection are reviewed, namely: (i) desk-based research and identification of research cases; (ii) access to cases; (iii) ethical review; and (iv) designing the interview schedule and conducting eighty semi-structured interviews. These phases did not necessarily follow a linear path but, for clarity, are "presented in a roughly sequential order" (Cope, 2010:440). Section 3.7 then outlines the three stages of data analysis adopted, namely: (i) transcription and description; (ii) classification; and (iii) coding. Again, despite the sequential ordering, data collection and analysis were undertaken concurrently, where analysis would highlight knowledge gaps, which would then be addressed through further research. Finally, conclusions are made and a link to the next chapter is provided.

To Denscombe (2002: 126), “there is no such thing as perfect research”, due to inevitable time and resource constraints. However, research designs, approaches and methods do vary in the extent they meet the following criteria:

- **Internal validity**: The findings are believable and match reality, since competing explanations will be anticipated and investigated (Creswell, 1994; Gorard, 2013).
- **External validity:** The findings are generalisable “beyond the specific research context” (Bryman, 2012:47).
- **Reliability:** It is possible for other researchers to replicate the findings, using the same research instruments (Golafshani, 2003). Reliability is synonymous with ‘academic rigor’, which means the data produced is “detailed, accurate and thorough” (Dictionary, O.E, 2015).
- **Practicality:** The methodology is feasible given the time and resource constraints imposed upon the research (Denscombe, 2002).

These criteria are referred to throughout this chapter, as the chosen research design, approach and methods are evaluated across the different sections. The next section outlines the research approach.

3.2 Research Approach

This study warranted ‘in-depth’ and ‘explorative’ research because the object of the study was an unexplored sector (Bryman, 2012; Ritchie and Lewis, 2013). Therefore, a qualitative approach was applied, since qualitative methods are concerned with the “interpretation and understanding” of unfamiliar issues (Eriksson and Kovalainen, 2015:4). The primary method of data collection was eighty semi-structured interviews with representatives from the UK *space* sector. Nevertheless, the research also had features of a quantitative approach. For instance, a limited amount of quantification of the data was undertaken, as the occurrence of key themes was assessed during their analysis (Bryman, 2012). Additionally, the interview data was supplemented with secondary sources of statistics and figures on the UK and global *space* sector (Figure 3.1). For example, "since 1992, the UK Space Agency has periodically surveyed organisations in the UK that supply to the *space* sector" (London Economics, 2015:3). It was appropriate to use these public datasets because their "scope and scale" and "quality in terms of completeness and validity" was not achievable through primary fieldwork, due to time and resource constraints (Gorard, 2013:29).

- IGS Priority Market Low Cost Access to *Space* (2015)
- National *Space* Policy (2015)
- Case for *Space* (2015)
- UK Spectrum Usage & Demand (2015)
- Size and Health of the UK *Space* Industry (2014)
- OECD, the *Space* Economy at a Glance (2014)
- Economic Impact of Satellite Broadband in Europe (2014)
- The case for EPS/METOP second generation: cost benefit analysis (2014)
- STFC Impact Report (2014)
- UK Space Agency, Review and evaluation: the National *Space* Technology Programme (2014)
- ESA, *Space* for our Future (2014)
- UK Space Agency, Strategy for Earth Observation from *Space* (2013-16)
- OECD Handbook on measuring the *space* economy (2012)
- Cost-Benefit Analysis for GMES (Copernicus) (2011)
- The Case for *Space*: The Impact of *Space* Derived Services and Data (2009)
- Severe *Space* Weather Events--Understanding Societal and Economic Impacts: A Workshop Report (2008)
- *Space* Technologies and Climate Change: Implications for Water Management, Marine Resources and Maritime Transport (2008)
- Met Office, the Public Weather Service's contribution to the UK economy (2007)

Figure 3.1: A list of secondary sources of data on the UK and global *space* sector.

Source: Author.

As with all research, the approach was based on an underlying theoretical assumption (Myers, 2013). The theoretical assumption is the relationship between theory and the data. The assumption underlying this research was 'abduction' (Bryman, 2012). Abduction involves both induction (conclusions drawn directly from the data) and deduction (the research set out to test or was defined by an existing theory), at different phases of the research (Henn *et al.*, 2006). Consequently, there was a 'circularity' to the research process, where the "role and place for theory in the research process emerges several times during the research process" (Eriksson and Kovalainen, 2015:31).

The next section outlines the first two phases of data collection, being desk-based research and the identification of the research cases.

3.3 Desk-based Research and Identification of Research Cases

The first phase of data collection was desk-based research. This involved a thorough review of the academic literature, which provided the "foundation and inspiration" for the study (Boote and Beile, 2005:3). The review explored, summarised, compared and critically analysed key concepts, theories and arguments that related to the research topic (Eriksson and Kovalainen, 2015:47). It also examined methods of data collection and analysis to ensure that the most appropriate methodology was adopted for answering the research questions. Furthermore, secondary data sources and web-based materials on companies were explored (ESA, 2013; Gov.UK, 2014; Gov.UK 2015; NASA, 2016 etc.). This process was valuable as it provided familiarisation with the industry and its present policy context. This research into existing data sources was also important to ensure that the proposed primary dataset did not already exist (Gorard, 2013). This knowledge helped with appropriately defining the object of the study.

3.3.1 Defining the Object of My Study

The production of *space* infrastructure and services is globally dispersed across multiple nation states. Therefore, research into the economic geography of the *space* sector was not restricted to the selection of cases (firms or organisations) from a single national context. To explore the possibility of a cross-comparison between the US and UK *space* sector, twelve pilot interviews were conducted in Florida, with a range of participants (Table 3.1). The US was chosen as a potential case for comparison because of its long history of dominance in the global *space* sector (OECD, 2012). Additionally, the original intention was to compare the governance systems of two national contexts, the differences between which would be greater if one was outside of Europe. Florida was selected over other US states because with Florida's Kennedy *Space* Center it gave the opportunity to develop an understanding of the launch process. Ideally, a number of US *space* states would have been visited (such as Virginia, Maryland and Texas) to provide a greater variation of interview participants and increase the external validity of the findings. However, limited research funding meant that, given the scale of the US, it was difficult to travel outside of Florida. The strategy for accessing cases and designing the Florida interview schedule (Appendix 1) will not be discussed here, since there is considerable overlap with the main study (Section 3.4 and Section 3.5). Similarly, the transcription process and three-stage analysis used was consistent with that outlined in Section 3.6.

Table 3.1: List of Pilot Interviews Conducted in Florida.

Interview participant representing…	**Brief description of US firm/organisation**	**Date of Interview**
***Space* Manufacturers**		
FloridaLaunchSiteContractor1	Launch site contractor.	31/03/2014
FloridaSubsystemsManufacturer1	Subsystems manufacturer.	01/04/2014
FloridaLaunchManufacturer	Launch vehicle manufacturer.	01/04/2014
Government Institution		
FloridaGovFacilitator1	The sole manager of the International *Space* Station U.S.	02/04/2014
FloridaGovFacilitator1	The sole manager of the International *Space* Station U.S.	02/04/2014
FloridaGovFacilitator1	The sole manager of the International *Space* Station U.S.	31/03/2014
FloridaGovFacilitator2	Independent innovation and technology company, created to foster growth across the economy through the exploitation of *space*.	01/04/2014
FloridaGovFacilitator3	A local government body that supports the expansion and diversification of Florida's *space* industry,	02/04/2014
FloridaGovFacilitator4	Drives state economic development across the global aero*space* enterprise.	03/04/2014
FloridaGovFacilitator5	The National Science Foundation's National Resource Center that promotes and educates candidates for technical employment.	05/04/2014
Own Consultancy Firm		
FloridaConsultant1	Experience from 32 years of Flight and Ground systems engineering and operational experience at Kennedy *Space* Centre.	05/04/2014
FloridaConsultant2	ISS programme Kennedy *Space* Centre.	04/04/2014

Source: Author.

The findings from the pilot study identified that the character of the US *space* sector is too different from the UK *space* sector to make a sensible comparison. This contrast primarily relates to the difference in scales of the two countries and their national *space* budgets. For example, the budget for the US *space* agency (NASA) is $17.2 Billion, whereas the UK Space Agency's budget is £1.2 Billion. Additionally, US states each have different priorities and compete against one another for government grants and contracts. Therefore, any research findings on Florida's *space* industry would not be generalisable to other US states. Florida is also 'launch orientated', whereas the focus in the UK is primarily on commercial satellites and applications. Highlighting the complexity of the US industry caused the need to reflect on the challenges of exploring more than one national context, given the time and resource constraints on the study. Consequently, the object of the study was defined as the UK *space* sector. This decision limited the external validity of the findings, but meant that resources were less stretched and that the data collected was "detailed, accurate and thorough" (Dictionary, O.E, 2015). Furthermore, whilst research cases based outside the UK were not involved, the desk-based research and semi-structure interviews still resulted in the collection of data on national comparisons (Section 3.6). The data collected in Florida was not wasted, since it provided valuable context on the launch process and sites (Chapter 4).

The decision to focus on the UK reflected my interest in the increasing level of government support for the *space* related activities since 2012 (Chapter 1). Additionally, since the UK's launch of the first international satellite in 1962, its involvement in the *space* sector has continued to grow "institutionally and commercially" (London Economics, 2015:1). For instance, the value of the UK *space* sector increased "from £6.5 billion in 2007" to "£11.8 billion in 2014" (Gov.UK, 2015b). The UK is particularly well represented in the satellite operating and *space*-enabled application market, as UK companies have captured 11.2% and 10.3% of the global market (London Economics, 2015). This market share is despite the relatively low UK civil government *space* budget, compared to other OECD nations (Figure 3.2).

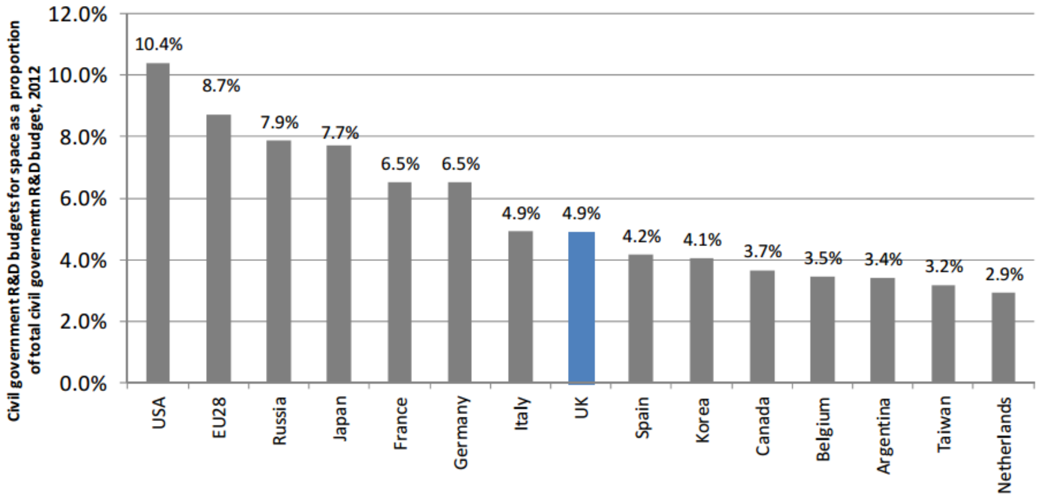

Figure 3.2: International comparison of civil government *space* R&D budget as a proportion of total civil government R&D budget.

Source: London Economics (2015:30).

3.3.2 Identification of Research Cases

The study used the firm as the principal unit of analysis, defined as the "fundamental agent of economic change" (Mulhall, 2012:73). As with any industry, no two UK *space* firms are the same, as they vary in size, specialism, strategic priority and location (Henderson *et al.*, 2001). Consequently, the research involved more than one case to capture this variation (Bryman, 2012). The cases were selected from the three sub-sectors of the UK *space* sector (Table 3.2): (i) satellite manufacturing; (ii) satellite operating and (iii) satellite-enabled application provision. These sectors each manage their own production projects and divisions of labour, and thus have distinctive roles, characteristics and spatial distributions (Smith, 1776; Harvey, 2014; Neilson *et al.*, 2014). It was important to research firms from all three sectors, to provide an in-depth view of the whole industry. Similarly, the research design accounted for the variation of firms within the three groups. For example, sub-groups were identified in relation to varying product focus (Table 3.2). The variation in cases maximised the internal validity of the research findings, since it increased the likelihood of competing explanations being investigated (Creswell, 1994; Gorard, 2002). It also ensured that the findings would be more generalisable "beyond the specific research context" (Bryman, 2012:47).

Table 3.2: Diversity of Research Cases.

Function (Groups)	**Sub-group of Cases**
Manufacturing	- Prime Satellite Manufacturers. - Launch Vehicle Manufacturer. - Ground Systems Manufacturer.
Operating	- Communications Operator (UK registered company). - Communications Operator (UK sales office).
Applications	- Earth Observation Applications Provider. - Geographical Information Services. - Telecommunications Provider.

Source: Author.

Component manufacturers, consultancy firms and infrastructure contractors also play critical roles in the UK satellite manufacturing sector. However, they were omitted from the case selection because the objective was to focus on manufacturers who deliver complete production projects (i.e. integrated satellites) and explore the 'nature and extent' of their relationships with satellite operators and application providers. Nevertheless, the input of component manufacturers, consultancy firms and infrastructure contractors provides relevant context for understanding the competitiveness of prime manufacturers. Therefore, their roles and characteristics are briefly outlined in Chapter 4, on the basis of the desk-based research and findings from my MSc study on the UK satellite manufacturing industry.

UK based satellite manufacturers, operators and value-added service providers were selected, to provide a first-account of their competitiveness, organisation and governance. They were identified through the following definitions:

(i) Satellite manufacturers: manufacture launch vehicles, ground systems and satellites.

(ii) Satellite operators: control the satellite when in orbit and sell communication bandwidth, position signals or observation data.

(iii) Satellite application providers: supply *space*-enabled services such as satellite television.

Additionally, government organisations were selected, to provide an external perspective on the firms (Table 3.3). Their involvement was also important for evaluating the impact of governance on the organisation and competitiveness of the UK *space* sector. Once again, the additional case group increased the internal validity of the data and helped to justify the external validity of the findings (Creswell, 1994; Gorard, 2002; Denscombe, 2002).

Table 3.3: The Role of the Government Organisations selected as Cases.

Organisation	**Role in the UK *Space* Industry**
(1) UK Space Agency (Department for Business Innovation and Skills)	• "Responsible for the government's civil *space* programmes, covering policy, regulation and delivery" (Gov.UK, 2015b:5). • "Manages the *space* projects and programmes under the Agency's responsibility against schedule and budget" (UK Space Agency, 2015). • "Manages the UK's relationship with other *space* agencies and trans-national organisations such as ESA (European Space Agency) and other international groups" (UK Space Agency, 2015). • Manages the statutory duties of HM Government under the Outer *Space* Act and develops *space* regulation policy that supports

	economic growth" (UK Space Agency, 2015). **Source**: UK Space Agency, 2015.
(2) European Space Agency (ESA)	• ESA is a European organisation aimed at coordinating the financial and intellectual resources of its members, so it can undertake programs and activities far beyond the scope of any single European country. • It was established in 1975 and headquartered in Paris, France. • It is funded by financial contribution from the Agency's 22 Member states, calculated in accordance with their gross national product, and in 2012 had a budget of €4.02 billion. • The European Council is ESA's governing body, who provide the basic policy guidelines within which ESA develops the European *space* programme. **Source**: ESA (2015).
(3) Satellite Applications Centre	• Established by the Technology Strategy Board. • One of a seven 'Catapult networks'– set up to help businesses take innovative ideas through to commercialisation. • "A world-class centre for the development and commercial exploitation of *space* and satellite-based products, services and applications". **Source:** SA (2013).
(4) Innovate UK	• Innovate UK supports the development of innovation from research to practical application and commercialisation. **Source:** London Economics (2015).
(5) Ofcom	• Ofcom is an independent regulator and competition authority for the UK communications industries. Ofcom was established in 2002 by the Office of Communications Act to represent the interests of citizens and consumers by promoting competition and protecting the public from harmful or offensive material. One of its main areas of activity is licensing and protecting the radio spectrum from abuse. **Source:** Ofcom (2016).
(6) UK *Space* Steering Board	• "Established to advise the Chief Executive, and an Audit Committee to provide guidance and formal oversight". **Source:** UKESNC (2015)
(7) G-STEP	• Mission is to promote the use of satellite, aerial and ground monitoring Earth Observation data in order to improve regional competitiveness. • Help businesses to access existing free software to process data to provide images and products. • It is the first Copernicus (formerly GMES) accelerator initiative in the UK. • Collaborates with the University of Leicester's Earth Observation (EO) and Geographical Information System (GIS) experts. **Source:** G-STEP (2015)
(8) RAL *Space*	• Works alongside the UK Space Agency. • Based at STFC's Rutherford Appleton Laboratory (RAL).

	• Carries out an exciting range of world-class *space* research and technology development. • Is at the forefront of UK *Space* Research. **Source:** RAL *Space* (2016)
(9) CASIS	• Centre for the Advancement of Science in *Space* (CASIS) • Mission is to maximise use of this unparalleled platform for innovation, which can benefit all humankind and inspire a new generation to look to the stars. • The organisation has been awarded by NASA the responsibility of inciting the imagination of entrepreneurs and scientists alike, accelerating and facilitating *space*-based research as well as creating public awareness of National Lab research and making *space* science more accessible to the world. • By carefully selecting research and funding projects, by connecting investors looking for opportunity to scientists with great ideas, and by making access to the station faster and easier, CASIS will drive scientific inquiry toward developing ground breaking new technologies and products that will tangibly affect our lives. **Source:** CASIS (2016)

Source: Author.

Additionally, two insurance companies were selected, to reflect the critical role private insurance plays in the UK *space* sector. Their inclusion was in response to the findings of some of the initial interviews, which highlighted the importance of insurance to the *space* sector. Similarly, a *space* legal practioner was selected, to provide the necessary context for the regulation of the sector. For example, it was important to understand the origins and complexities of the legal frameworks and international treaties which govern the UK *space* sector (such as the Outer *Space* Treaty). Finally, the UK Minister of State for Universities and Science from 2010 until July 2014 was selected, since he had publically been a strong supporter of the *space* sector while in post and could provide insight into the rationale behind government backing of the UK satellite industry. The next section outlines the sampling strategy used for selecting the cases.

3.3.3 The Sampling Strategy

A purposive sampling method was used to allocate individual cases to the various subgroups (Shaw, 1999). It selected ‘information rich cases’, which yielded “insight and in-depth understanding” on “issues of central importance” to the research questions (Patton, 2002:273). This “non-probability form of sampling” was appropriate for the exploratory nature of the study (Bryman, 2012:418). This impacted on the number of cases chosen for each sub-group. For example, all four prime satellite manufacturers were selected to provide the necessary insight into that part of the industry. This reflected the central role of prime manufacturers in the industry. In contrast, only 28% of ground systems manufacturers and 20% of launch vehicle manufacturers were selected, on the basis that they play a less central role.

The form of purposive sampling used was ‘stratified’, whereby cases were “selected in proportion to one or more characteristic in the population” (Gorard, 2013:81). The two characteristics were size (as measured by the number of employees) and function (manufacturing, operations and application provision). This stratified approach helped to ensure a maximum diversity of research participants, which was important for accurately characterising the industry and maximising internal validity (Bryman, 2012; May, 2005; Creswell, 1994; Henderson *et al.*, 2001).

A database was created of UK satellite firms from the case groups, using the UK *Space* Directory. The UK *Space* Directory is produced by the Knowledge Transfer Network (KTN) and lists profiles of UK satellite manufacturers, operators and application providers. The profiles (Figure 3.3.) included the firms’ function in the sector, their capabilities and location.


i. Satellite / payload design / manufacture

Space Upstream

4LINKS LIMITED

Suite EU2, Bletchley Park, Sherwood Drive, Milton Keynes, MK3 6EB

Contact: Paul Walker, Founder

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E: info@4links.co.uk

W: www.4links.co.uk

4Links

4Links is a world authority on SpaceWire, renowned for quality products that save money and delay, solving problems throughout the development of satellites and subsystems.

AIRBUS DEFENCE AND SPACE

Gunnels Wood Road, Stevenage, Hertfordshire SG1 2AS

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W: www.airbusdefenceandspace.com

Airbus Defence and Space is the world's second largest space company with revenues of around €13 billion per year and more than 38,000 employees.

Figure 3.3: A sample of two profiles listed in the UK *Space* Directory.

Source: ISSUU, 2016.

The firms in each case group were categorised according to size, as measured by the number of employees. This information was sourced from the 'Financial Accounts Made Easy' (FAME) dataset, which lists information (e.g. name, location, industry affiliation) on UK VAT registered firms (Bureau Van Dijk, 2016). However, FAME is not a comprehensive register, since small firms are exempt from reporting their annual accounts and new market entrants can take up to two years to submit their first annual accounts (BERR, 2009). Therefore, FAME did not have the details of thirty-three (38 per cent) of the cases identified by the UK *Space* Directory. Consequently, extra searches on firm size had to be conducted through company websites, trade association membership lists and LinkedIn pages.

A sample of firms was then selected, which were proportionate to the size and function (i.e. manufacturing, operations and application provision) of firms in the database (Table 3.4). For example, three times as many 'downstream' (from the operating and applications group) cases (twenty-two) were selected, compared to upstream cases (seven). This was proportionate to the number of firms in the database (sixteen upstream firms vs. forty-eight downstream firms). Similarly, the sample proportionately represented different sized firms.

Table 3.4: The Result of the Purposive Sampling Strategy.

Function	Size of Firm (number of employees)	Database of Firms (from the UK *space* directory) (64 cases)	Sample (29 cases)
Manufacturing			
Prime Satellite Manufacturers	Large Firm (>250)	2	2
	Medium Sized Firm (50-250)	2	2
Launch Vehicle Manufacturer	Small Firm (10-49)	5	1
Ground Systems Manufacturer	Medium Sized Firm (50-250)	1	
	Small Firm (10-49)	5	2
	Micro Firm (<9)	1	
Total number of cases (% of total)		**16 (25%)**	**7 (24.1%)**
Operating			
Communications Operator (UK company)	Large Firm (>250)	5	2
	Medium Sized Firm (50-250)	3	2
	Small Firm (10-49)	3	2
	Micro Firm (<9)	1	1
Communications Operator (UK sales office)	Small Firm (10-49)	4	3
Total number of cases (% of total)		**16 (25%)**	**10 (34.5%)**
Applications			
DTH Broadcaster	Large Firm (>250)	5	2
Earth Observation Applications Provider	Large Firm (>250)	4	2
	Medium Sized Firm (50-250)	/	/
	Small Firm (10-49)	8	3
	Micro Firm (<9)	11	3
Geographical Information Services	Large Firm (>250)	/	/
	Medium Sized Firm (50-250)	2	1
	Small Firm (10-49)	/	/
	Micro Firm (<9)	2	1
Total number of cases (% of total)		**32 (50%)**	**12 (41.4%)**

Source: Author

Additionally, the seven government organisations identified in Table 3.3, three regulatory firms (insurance and legal services) and the government minister were identified as 'information-rich cases'. In total, forty cases were selected (twenty-eight satellite firms, three regulatory firms, nine government organisations). Since it is not possible to interview a firm or organisation, reliance was placed on interviews with senior representatives from each. This carried disadvantages, as the views of individuals are subject to "distortions and misrepresentations" (Jones, 2005:200). This can impact on the reliability of findings if participants utter their "own voice", instead of recounting the values or experiences of their company or organisation (Oinas, 1999:358). To mitigate this risk, multiple representatives were interviewed from the largest firms and organisations (Table 3.5). This increased the reliability of the findings, since it allowed case data to be triangulated and tested. Additionally, the government organisations are divided into separate units, thus it was important to interview a representative from each. Multiple firm representatives were also valuable for exploring complex issues, as it presented the opportunity to revisit certain areas. For example, orbital slot and frequency spectrum allocation is a highly complex process and so the research benefitted from interviews with multiple participants from the operating sector (even though the companies were smaller).

Table 3.5: The Number of Interviews by Function.

Function	**Firm Code** (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)	**Number of Interviews Participants (Total = 80)**
Prime Satellite Manufacturers	L.Prime1	4
	L.Prime2	3
	M.Prime1	1
	M.Prime2	1
Launch Vehicle Manufacturer	S.LauncherManufacturer1	1
Ground Systems Manufacturer	S.GroundSystems1	1
	S.GroundSystems2	1

	Total	**12**
Communications Operator (UK company)	L.Operator1	4
	L.VSATApplications1	2
	M.Operator1	2
	M.Operator2	2
	S.VSATOperator1	1
	S.Operator1	3
	Mi.Operator1	1
Communications Operator (UK sales office)	S.Operator1	2
	S.Operator2	2
	S.Operator3	2
	S.Operator4	1
	Total	**22**
DTH Broadcaster	L.DTHApplications1	1
	L.DTHApplications2	1
Earth Observation Applications Provider	L.DataApplications1	1
	L.DataApplications2	1
	S.DataApplications1	1
	S.DataApplications2	1
	S.DataApplications3	2
	Mi.DataApplications1	1
	Mi.DataApplications2	1
	Mi.DataApplications3	1
Geographical Information Services	M.DataApplications1	4
	S.DataApplications1	1
	Total	**16**
Satellite Insurance Provider	L.Insurer1	1
	L.Insurer1	1
Space Legal Practioner	L.Law1	1
	Total	**3**
Government Minister	GovMinster1	1
Government Policy Organisation	GovPolicy1	1
	GovPolicy2	3
	GovPolicy2	6
Government Facilitator of Policies	GovFacilitator1	3
	GovFacilitator2	5
Government Regulator	GovRegulator1	3
Government Defence Organisation	GovDefence1	2
Government Research Centre	S.GovResearch1	1
	S.GovResearch2	1
	L.GovResearch1	1
	Total	**27**

Source: Author.

In total, eighty participants were interviewed. This sample size was chosen in the early stages of the research design and considered an appropriate number for achieving "informativeness, reliability and generalisability" with the research findings (Charles, 2000:319). For instance, the sample size was not too small that it avoided "missing out on potentially valuable results" (Gorard, 2013:85). Additionally, the size was not disproportionate to the available resources (including time and money), allowing a thorough investigation of the "complexities and subtleties" of each case and a 'depth' of understanding (Denscombe, 2002; Marshall, 1996). Nevertheless, this number of participants was flexible around the data needs of the research, with recruitment only ending when it was apparent that new data would not significantly add to the development of theory (Spencer *et al*., 2003). It was assumed that each participant selected would agree to take part in the study or otherwise would be replaced by a representative from a case in the same sub-group (Gorard, 2013).

3.4 Access to Cases

It was critical to achieve a high participation rate, to maximise the external validity of the research findings (Bryman, 2012:47). Consequently, considerable time was spent in developing effective 'access strategies' for recruiting participants (Bryman, 2012; Berg, 2004). The primary recruitment method was connecting with participants via LinkedIn. LinkedIn was launched in 2002, as a "business-oriented social networking site" (Papacharissi, 2009:201). It allows users to create their own professional profile and connect with contacts "within and outside their professional networks" (Papacharissi, 2009:200).

LinkedIn was an appropriate access strategy because of its popularity amongst the satellite community, who use it as an "inexpensive tool for networking with potential customers and prospective employees" (Witzig *et al*., 2012:118). For instance, as of the 31st August 2016 there were 52,505 UK LinkedIn members associated with the *space* sector.

The primary advantage of LinkedIn, above other recruitment methods, is it provides details on the positions and past-experiences of participants through their profiles. This assisted with the purposeful targeting of senior representatives, who were most likely to be well-informed about the competitiveness, organisation and governance of their firm or organisation. Additionally, knowledge of the participants' experience meant that, if relevant, it could be referred to in the interviews. For example, participants were asked to reflect on the differences between their present and previous posts in the industry. This helped to highlight the differences between firms, which contributed to the understanding of the organisation of the industry.

The participants were found using LinkedIn's 'Advanced People Search' tool, which facilitated searches of their company name or broader keywords (such as satellite manufacturing or satellite operating) (Figure 3.4).

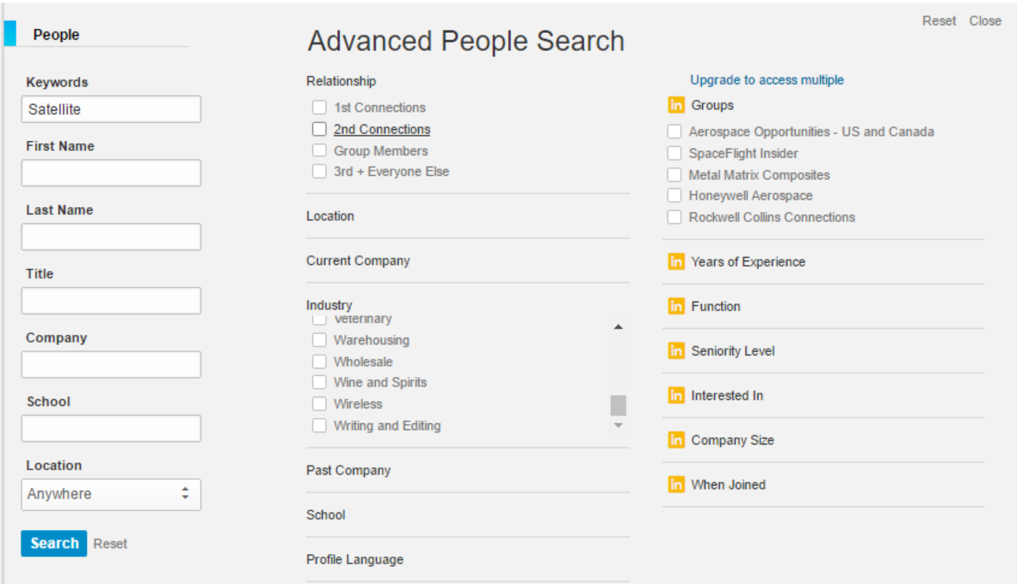

Figure 3.4: The 'Advanced People Search' on LinkedIn.
Note: The user is able to specify the 'location' and 'relationship' with the individual.

Source: LinkedIn (2016).

Once identified, the individual was invited to 'connect' with me. This involved sending a short introductory message (140 characters), which was a personalised version of a template provided by LinkedIn (Figure 3.5). Time was taken to personalise the message to make the participants aware of the shared interest and encourage them to connect.

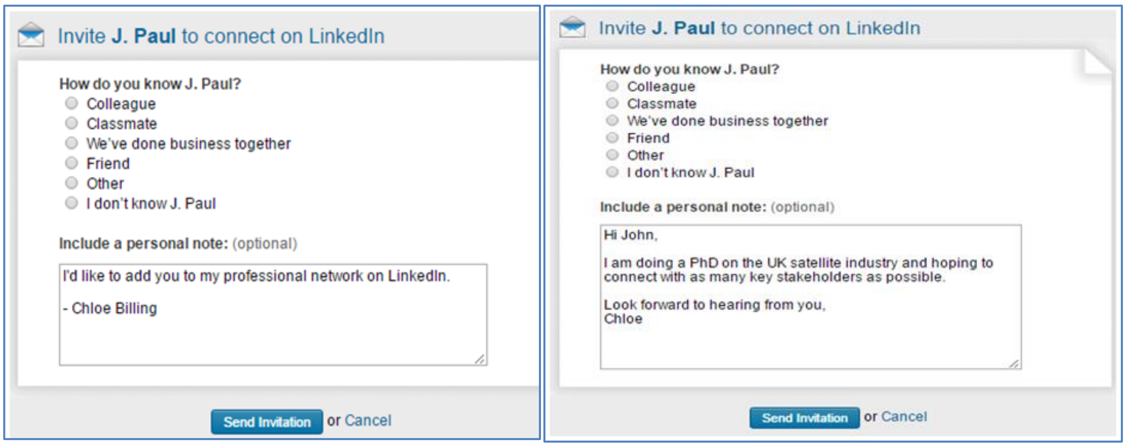

Figure 3.5: Comparing a template and personalised message for connecting on LinkedIn.

Source: LinkedIn (2016).

Out of the ninety people contacted, eighty-five agreed to connect (94%). Once connected, I requested the participation of the stakeholder in the research project via the private message tool. It was recognised that the majority of users check their LinkedIn account when on the move, i.e. when on their way to and from work. Consequently, the request messages were designed to be short and concise (so that they could be quickly dealt with), with the intention that further details of the study would be provided if and when the connection[4] showed interest. Again, the messages were personalised and stressed the potential value of the connections' contributions to the research project. It was important to demonstrate an interest in the connections' jobs and career, to build up relationships and encourage them to want to assist with the research. Consequently, many hours were spent studying the profiles of connections and learning about their careers and skills. One of the advantages of doing this was, when interviewing connections, their key attributes were already known by me. It also helped the development of the understanding of the industry and the characteristics of each sector (i.e. manufacturing, operating and applications provision).

Seventy-nine (92%) people replied to the private message stating that they would be interested in hearing more about the study. A large number provided their email address at this point for further contact. In two cases, the connection asked to be called to discuss the project. A more formal cover letter (Appendix 2) was then sent to the connections via LinkedIn or email, outlining: (i) the research aims; (ii) a request for their participation in an interview; (iii) an estimation of how long the interview would be and when and where it would be conducted; (iv) data protection details; (v) my contact details and a request for a

[4] On LinkedIn a 'connection' is another individual (LinkedIn member) that agrees to be your contact and 'connect' with you (LinkedIn, 2016b).

response within three days; and (vi) the contact details of my supervisors to help prove my credentials (Valentine, 2005b).

Seventy-three of the LinkedIn connections agreed to participate. Three did not reply and the other three were unable to participate. The reasons given for a ‘no response’ were: (i) they could not get permission from their PR department; (ii) their job involved lots of travelling, thus arranging an interview would be unfeasible; (iii) they did not feel well suited to the research. In one case, a firm had been wrongly identified as a satellite application company, when it was more involved in mobile communications. This potential interview was therefore replaced in the sample with another firm from the UK Space Database.

Six firms selected via the purposive sample were not represented on LinkedIn. These were contacted via the email address provided on their company websites. The request email was consistent with that sent to the LinkedIn connections (Appendix 2). Four of the cases replied on the same day. For the two cases that did not respond, another email was sent after three days and in one case the firm was telephoned. Five of the firms contacted via email agreed to participate and one did not respond. The ‘non response’ case was replaced with another firm from the same case group in the database, which was contacted via a representative on LinkedIn who agreed to participate. An email was also sent to request an interview with the UK Minister of State for Universities and Science (2010-2014). This followed a review of the literature on ‘elite interviews’ (interviewing “people who are well known, distinctive or famous”) (Moore and Stokes, 2012:439). The minister had a personal interest in the *space* sector and was thus motivated to participate in the study.

In total, eighty-seven requests were sent and eighty individuals agreed to participate in the study. Therefore, the final participation rate was 92%. Because cases with 'no responses' were replaced via the purposeful sampling method it was determined that they would not substantially impact on the findings of the study (Gorard, 2013). The relatively high participation rate was attributed to the LinkedIn access strategy and the passion that members of the UK satellite industry have for their sector. Additionally, as an under-researched area, there was a reduced likelihood of 'research fatigue' affecting participation rate (Harvey, 2010). Furthermore, relationships with nine of the research participants had already been developed in the MSc study. To those participants, I appeared more as an "insider", than an "outsider" and this positionality helped with securing their participation (Herod, 1999:321)

Before any primary data collection could take place, it was essential to first conduct an ethical review of the research plan. Details of this crucial phase of the research process are outlined in the next section.

3.5 Ethical Review and Practices

The ethical review followed the guidelines set out by the ESRC (ESRC, 2015) and the University of Birmingham. The purpose of the review was to put a protocol in place, which would protect the interview participants, the researcher and ethics of the research process. The outcome of this preparation was best ethical practice being upheld throughout the research process. These ethical practices are outlined below.

First, the participants' involvement in the study was voluntary and prior to receiving a consent form (Appendix 3), participants were provided with an information sheet (Appendix 2), which outlined the research in detail (Crow *et al.*, 2006; Guillemin and

Gillam, 2004). The information sheet informed the participants: (i) how long the interviews would take; (ii) how the data would be used; (iii) that their name and details would be anonymised, and (iv) that they had rights to withdraw, without any consequences, from the project at any time.

Second, all data was kept confidential, as both electronic and hard copies of interview transcripts were stored securely, through computer password protection and a locked filing system. Participants' names were also anonymised, by assigning each interview to a code (Appendix 4). Where there was more than one participant from a firm/organisation, they were differentiated by letters. For example: L.Prime1a, L.Prime1b, L.Prime1c and L.Prime1d. In addition, if participants mentioned the names of other firms then they too would be anonymised to avoid otherwise breaching confidentiality (McLellan *et al*., 2003:66).

Finally, giving them the choice of location for the interviews ensured the participants felt comfortable in a familiar environment. Interviews were mainly conducted inside the participant's workplace and home visits were avoided so as to reduce the risk of harm to the researcher (Valentine, 2005). Furthermore, the interview structure was non-leading and the interviews were transcribed verbatim (Holstein and Gubrium, 2004). This avoided missing any data and ensured the participants' viewpoints were accurately represented. This was both an ethical consideration and important for the internal validity of the findings.

3.6 Designing the Interview Schedule and Implementation

The next phase of data collection was semi-structured interviews with representatives from the selected sample of firms and government organisations. Interviews were an appropriate research method because they encouraged “wide-ranging” discussions, which covered a breadth of issues (Valentine, 2005:110). This discussion format increased the likelihood of the findings matching reality and competing explanations being explored (internal validity) (Creswell, 1994; Gorard, 2002). Furthermore, interviews presented the opportunity for themes to be examined in greater depth than a questionnaire format would allow (Kitchin and Tate, 2000; Valentine, 2005). The outcome was a reliable dataset, which was detailed and thorough (Dictionary, O.E, 2015).

The data was collected in a single time period, between the 7th November 2014 and 14th July 2015. This ‘snap-shot’ approach helped to minimise the impact of ‘external time related events’ on the research findings (Henn, 2006; Gorard, 2013). For example, changes to government policies would alter the governance of the industry, which may impact on the organisation and competitiveness of firms (Bechhofer and Paterson, 2012). Additionally, the approach was more practical than a longitudinal research design, as time constraints imposed on the research did not allow for “repeated data collections” (De Vaus, 2001:176).

3.6.1 Interview Schedule

Appropriate question selection was crucial, with a balance of ‘content mapping’ and ‘content mining’ questions. Content mapping questions identify the “issues that are relevant to the participant”, whilst content mining questions explore the details and “generate an in-depth understanding” (Legard *et al*., 2013:143). This balance of question forms was important for addressing all dimensions of the research questions. Additionally, the varying format helped to maintain conversation flow and minimise boredom of the participants (Kitchin and Tate, 2000:217). All questions were “clear, concise and easy to understand”, which left the participants with “no uncertainty about the sort of information sought” (Kitchin and Tate, 2000:217; Legard *et al.*, 2013:155). In total, there were six revisions of the interview schedule before the final version. A short pre-amble was also prepared for the start of the interview to remind the participant of the focus of the study. Critically, the questions and pre-amble were non-leading to maximise the internal validity of the findings (Gerson and Horrowitz, 2002).Some of the questions used were consistent with those from my MSc dissertation research, due to the crossover with their topics (Billing, 2013).

To ensure that the questions were non-leading, clear and relevant to the research questions, the interview schedule was piloted (Van Teijlingen and Hundley, 2001). This feasibility study involved pre-testing the research instrument on five participants, randomly selected from the sample. These five pilot interviews were recorded and the effectiveness of the interview schedule was self-evaluated on the basis of responses and ease of analysis (Kitchin and Tate, 2000). It was concluded that the pilot interviews had been successful (i.e. no alterations were needed to be made to the interview schedule), allowing their data to be included in the main analysis.

The interviews ranged in length from thirty to ninety minutes and were semi-structured, consisting of a set of pre-arranged questions, which varied in wording and sequence depending on the participant (Kitchin and Tate, 2000). The semi-structured format made it possible to “probe beyond the answers”, following-up on interesting responses and seeking clarification where necessary (May, 2011:135; Valentine, 2005). The interview structure divided into three parts: (i) background/ product questions; (ii) organisation and governance of production; and (iii) impact of regulation. These related to the three research themes (competitiveness, organisation, and governance) and were investigated via a series of questions. The questions varied depending on the case group (manufacturing, operations, applications, insurance, legal, government agency etc.) of the firm or organisation that the participant represented (Appendix 5).

3.6.2 Interview Process

A successful interview process was dependent on effective preparation (Schoenberger, 1991). In preparation, a study of the profiles of the firms and organisations was conducted via their websites, the UK *Space* Directory and public reports (Figure 3.2). A familiarisation exercise with respect to industry-specific terminology was undertaken, which helped ensure I maintained a level of professionalism during the interview process (Valentine, 2005; Turner, 2010). As part of the preparation, I attended a *space* law and policy course in October 2014. The one-day intensive course was led by the London Institute of *Space* Policy and Law (ISPL) and offered interactive lectures covering the topics outlined in Figure 3.6. This course provided me with a necessary introduction to the regulatory governance of the UK *space* sector. It was critical to develop a foundational level of understanding on the unique aspects of the industry before interviews could begin.

Subject:

- The *space* environment and *space* technology
- Orbits, their characteristics and management, and types of *space*craft
- Spectrum management
- The law governing *space* activities: principles & sources of *space* law, including conventions and treaties, national law and policies
- Peaceful use of *space*, military activities & arms control, security
- Property rights, commercial activity
- Risk, liability and insurance, debris
- The law as relates to specific applications: telecommunications and broadcasting, remote sensing, scientific experiment and exploration, manned activities including the International *Space* Station, unmanned activities

Figure 3.6: Subject matter of ISPL lectures.

Source: ISPL (2016).

Sixty (75%) of the interviews were conducted face-to-face. This had the distinct advantage of being “more personal in nature”, helping to build rapport between myself and the research participants (Kitchin and Tate, 2000:216). Building rapport was important as it encouraged openness and trust, which increased the likelihood of reliable research findings. Face-to-face exchanges also had the advantage of allowing me to more effectively gauge participants’ reactions to questions, in relation to their body language and facial expressions (Kitchin and Tate, 2000). 85% of the face-to-face interviews were held inside the participants’ firms or organisations. This increased the likelihood of the interviewee feeling relaxed, as within their own environment (Valentine, 2005:118). It also often presented the opportunity for me to have a tour of the facilities, which helped to maximise the understanding of the character of the business/organisation. On nine occasions, the research participants were away from their offices and the interviews were conducted in coffee shops. This more public setting still facilitated a personal exchange, but it was more difficult to focus because of surrounding noise.

Twenty (25%) of the participants opted for their interview to be conducted by telephone. The most common reason for this was that they would be working from home, so felt a telephone exchange would be more appropriate. These interviews were more difficult to conduct, as it was harder to build rapport with the participants (Sturges and Hanrahan, 2004; Irvine *et al*., 2013). Additionally, it was more difficult to gauge whether participants had paused or finished answering a question during telephone interviews, meaning they were often interrupted. Nevertheless, the telephone interviews were still an “acceptable and valuable method of data collection” (Oltmann, 2015:147).

All of the interviews were digitally recorded, with permission from the participants, to provide "a permanent record" of the data (Robson, 2002:290). Recording removed the need to take extensive notes during the interview, allowing the devotion of full attention to the participants (Legard *et al.*, 2013). Full attention was required to ensure that the participants' answers were given an appropriate response "without introducing bias" (Kitchin and Tate, 2000:215). It was equally important that I dressed in smart business attire, as this was appropriate for the research setting and demonstrated professionalism (Valentine, 2005).

3.6.3 Positionality

The ontological approach applied to this research method was 'constructionism', meaning the data was collected "through social interaction" and its interpretation was influenced by the researcher's 'lens' (Bryman, 2012:19). Consequently, a potential criticism of the research could be that it was too "impressionistic and subjective" (Bryman, 2012:405). This refers to how the identity or positionality of the researcher (i.e. sex, ethnicity, social background and personality) could have potentially impacted on the data collection and research findings (Valentine, 2005; Rose, 1997). For example, the "values and judgements of a researcher" (which is a product of their positionality), can influence question selection (for interviews) and the focus of analysis (Creswell, 1994; Stern, 1979).

Although, impossible to achieve "absolute neutrality" it was important, to 'act in good faith' to remain as objective as possible (Moser, 2008:383; Bryman, 2012; Holstein and Gubrium, 2004). This required me to be critically aware of my partiality, ensuring personal values and judgements had minimal influence on the interview structure and analysis process. In addition, I remained self-reflective throughout the research process, checking that my positionality was not swaying the conduct of the research and causing me to neglect certain research findings (Bryman, 2012; Stern, 1979).

3.6.4 Additional Data Collection: Attending the UK *Space* Conference

Additional data was collected at the UK Space Conference (UKSC) in Liverpool (13th-15th July 2015). The UKSC conference is held every year and described as "an unmissable gathering for the entire UK *space* community" (UKSpace, 2015). The conference title was '*Space*-enabled Futures', aimed at delivering strategies for the future growth of the UK *space* sector. It involved twenty-five parallel sessions, which covered a range of topics relevant to the satellite manufacturing, operating and applications sectors. These sessions were highly informative and supplemented information from the existing dataset. Furthermore, over one thousand delegates from the UK *space* community attended the event. This provided the opportunity to reconnect with many of the interview participants, allowing the collation of opinions on the initial research findings and follow-up on any research gaps. This maximised the reliability of the research findings, as it helped ensure the data produced was "detailed, accurate and thorough" (Dictionary, O.E, 2015). Two of the eighty interviews were also conducted at the UK *space* conference, since the two participants suggested it as an obvious event at which to meet.

3.7. Data Analysis

There were three stages of data analysis: (i) transcription and description; (ii) classification; and (iii) coding. First, the interviews were transcribed verbatim and the key findings of each were briefly summarised (Kitchin and Tate, 2000). Transcribing was a lengthy process, since transforming speech into text takes time and is "not without challenges" (McLellan, 2003:66). For example, issues such as incomplete sentences, overlapping speech and the interruption of background noise were encountered. To help during transcription, the below three guidelines were followed (Mergenthaler and Stinson's, 1992:129; McLellan, 2003):

i. Keep word forms, the form of commentaries, and the use of punctuation as close as possible to speech presentation.
ii. Keep text clearly structured with line numbers and distinctions between the interviewer and interviewee.
iii. The transcript should be an exact reproduction, generating a verbatim account.

The brief summaries of each transcript "reflected the initial processing of the information by the researcher" and presented the opportunity to identify potential themes for later analysis (Fereday and Muir-Cochrane, 2006:86). The next stage was to "interpret and make sense of the data", through highlighting significant quotes and linking them to the research questions and the competitiveness, organisation and governance literature (Bird, 2005; Kitchin and Tate, 2000). This was identified as the 'classification' stage.

Finally, based on the classification stage, a set of categories and sub-categories (Kitchin and Tate, 2000) were identified. The data was then broken down into component parts and assigned to the categories using coding (Appendix 6) (Bryman, 2012). Coding involves the "assignment of interpretative tags to text based on categories or themes" relevant to the research questions (Cope, 2010:440). To Boyatzis (1998:161), a theme is:

> "…a pattern in the information that at minimum describes and organises the possible observations and at maximum interprets aspects of the phenomenon"

The coding stage followed four key steps: (i) developing the code manual; (ii) applying the codes; (iii) connecting the codes; and (iv) corroborating and legitimising coding (Fereday and Muir-Cochrane, 2006). These steps are outlined below.

3.7.1 Developing the code manual

The development of a code manual was a crucial stage in the data analysis because it provided a data management tool for organising the data (Weston *et al*., 2001:387). The codebook included the codes, definition and key words/phrases from transcriptions. For example, one category was '*space* geography':

- Code: O_SG
- Description: Any comment relating to the spatial configurations of satellite in orbit.
- Key words: Orbit, polar, GEO, LEO, MEO, Earth, Frequency, Spectrum, Slot.

Initially, the research questions and theories from the literature provided a set of codes (i.e. deduction), since the theoretical approach underlying the research was abduction (involving both deduction and induction) (Weston *et al*., 2001: 384). For instance, the three broadest categories or codes related to the three key research areas, namely the competitiveness, organisation and governance (Appendix 6). However, the analysis was not confined to these preliminary codes, as inductive codes were also identified as new themes were also observed (Fereday and Muir-Cochrane, 2006:88). The inductive codes were the sub-categories shown in Appendix 6 and represent where the data was allowed to "speak for itself" (Welsh, 2002:5). There were several revisions of the codes, as their reliability was tested after being applied to multiple transcripts and checking for consistencies. These revisions did not involve removing codes from the code manual, but merging some categories (four in total) where appropriate.

3.7.2 Applying the codes

The categories were applied manually to printed versions of the interview transcripts. Sections of the data from electronic copies of the interviews were simultaneously highlighted, labelled, copied and pasted into relevant word documents, separating the three themes and related categories (Spencer *et al*., 2003). A manual approach to coding was utilised instead of electronic coding (i.e. by using the computer software NVivo) because based on my MSc experience and from discussions with colleagues I felt that manual coding allowed me to get closer to the data. As argued by Welsh (2002:8),

> "…there are two camps, those who feel that software is central to the analysis process and those who feel that is unimportant and in fact can result in the "wrong" kind of analysis taking place".

I fall into the 'second camp' after observing (from my own and other colleagues' experiences) how time spent on perfecting coding in NVivo can distract from meaningful analysis. Additionally, I have personally found that manual methods are more conducive to me taking time to "sit back and think about possible thematic connections across the data" (Welsh, 2002:8).

3.7.3 Connecting the codes

The codes across the various transcripts were then connected, which involved identifying patterns in the data or similarities and differences between different cases. This highlighted where there was consensus or disagreement in response to research questions (Fereday and Muir-Cochrane, 2006:87). These comparisons or connections identified then formed the basis of the research discussion (Spencer *et al*., 2003; May, 2011).

3.7.4 Corroborating and legitimising coding

The last stage was corroborating or 'confirming the findings' (Crabtree & Miller, 1999:170). This helped ensure the final conclusions are believable and match reality (Creswell, 1994; Gorard, 2002). This involved critically inspecting "the interaction of text, codes and themes" to ensure the internal validity of the accounts (Eriksson and

Kovalainen, 2015:34). Ideally, this would also have been done by several other individuals to check that there was consistency with the coding method. However, resource constraints meant that this was not possible. Instead, I maintained contact (via LinkedIn) with the research participants throughout the research process, allowing the cross-checking of research findings against the views of participants. As argued by Eriksson and Kovalainen (2015:69):

> "…when a close relationship has developed, whether planned or not, the participants may be more inclined to give feedback on empirical analysis/research writing/conclusions"

This helped compensate for the absence of multiple perspectives to legitimise the coding method.

3.8 Conclusion

The design, approach and methods adopted for this study were chosen because they are practical, whilst maximising the internal validity, external validity and reliability of the research findings. For instance, the chosen research design accounts for the diverse range of economic actors involved in the *space* sector and maximised the external validity and reliability of the research findings. Similarly, the 'explorative' and 'in-depth' qualitative approach to the research is appropriate for studying an unexplored industry (Bryman, 2012). Additionally, semi-structured interviews encouraged "wide-ranging" discussions, which increased the likelihood of the findings matching reality and competing explanations being explored (internal validity) (Creswell, 1994; Gorard, 2002). The next chapter forms the first part of the combined analysis and discussion and is focused on characterising the UK *space* sector.

CHAPTER 4

THE STRUCTURE, *SPACE* GEOGRAPHY AND GROUND GEOGRAPHY OF THE *SPACE* SECTOR

4.1 Introduction

When one thinks of outer *space,* there is a tendency to think of rockets and missions to the moon. There is a similar assumption, that the *space* sector is highly complex, largely unknown and unlike other sectors. This is true in part, given that *space* is a physical environment unlike any other, which poses distinctive technical challenges and financial risks (London Economics, 2015). However, the production of *space* hardware and satellite applications is grounded in the economy in the same way as other sectors. Consequently, features of its manufacturing and service activities are common across other sectors, such as consumer electronics, automotive and aviation. This chapter identifies both the common and distinctive features of the *space* sector in an overview of its structure, providing the necessary context for understanding the organisation, competitiveness and governance of the UK satellite industry. Additionally, the chapter explores the geography of the industry and how satellite ground stations and launch sites in particular are restricted to certain locations. This will contribute to the 'geography still matters' debate (Krugman, 1993; Dupuy *et al*, 2010; Sheldon, 2014). Outlining the *space* and ground geography of the sector is also an important part of understanding its contextual framework (Cooper and Fox, 1990: Bryson, 2009).

The chapter deals with three integral parts of the *space* sector, all of which interact: (i) the structure; (ii) *space* geography; and (iii) ground geography. The analysis begins by exploring the distinctive roles and characteristics of three separate but related sub-sectors of the satellite industry. The sub-sectors are each responsible for different production projects and include manufacturers of *space* assets, satellite operators and satellite-enabled service providers. The differences, yet mutual dependence between these sub-sectors is a specific focus, since this is critical for developing an understanding of the organisation of production in the industry. The distinctive geography of *space* orbits and frequency spectrum is then explored, identifying why these are a ‘contested’ and limited resource. This is followed by a discussion of the ground geography, exploring the relationship between ground stations, launch sites and satellite orbits. The chapter concludes by highlighting the interactions between the structure of the industry, *space* geographies and ground geographies.

4.2 The Structure of the *Space* Sector

This section outlines the structure of the *space* sector by characterising the production projects and economic agents involved. It first provides an overview of the structure. The remainder of the section then focusses on the production projects of *space* manufacturers, satellite operators and satellite-enabled application providers in turn, as well as their interdependencies.

4.2.1 Overview of Structure

The *space* sector encompasses three segments or sub-sectors, which despite each managing their own production projects and divisions of labour, are interdependent. The three sub-sectors (Figure 4.1) are *space* manufacturing, satellite operations and satellite applications.

They each have distinctive roles, characteristics and spatial distributions. Additionally, the sub-sectors have varied profit margins, with operators and service providers generating higher 'Earnings Before Interest and Taxes' (EBIT) than the manufacturers and launch providers (Figure 4.1).

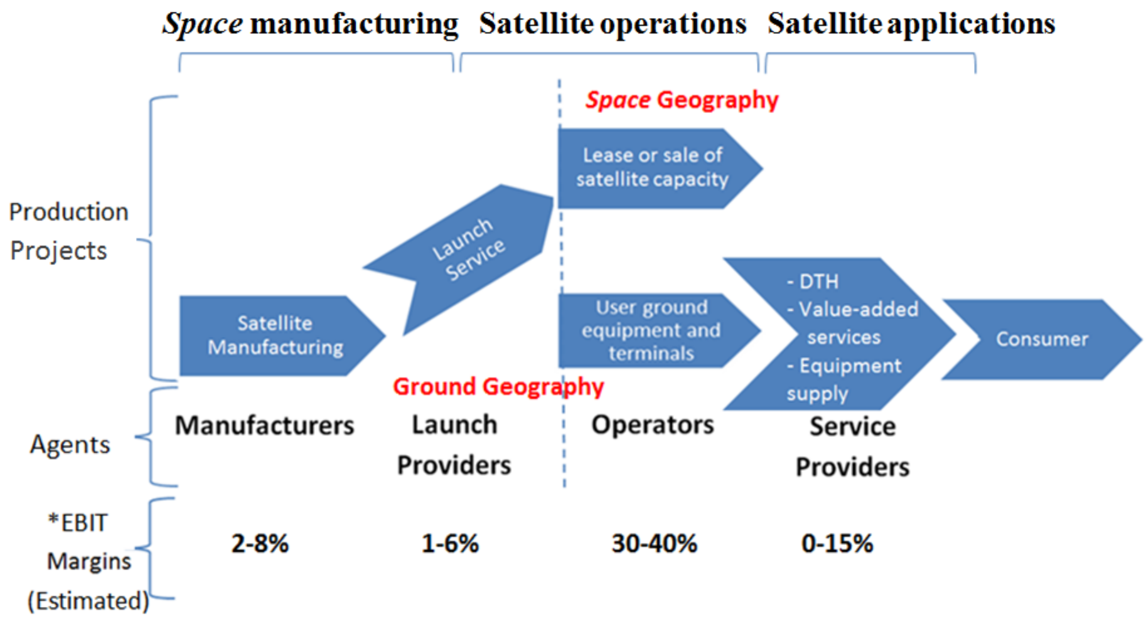

Figure 4.1: Satellite production projects.

Note: Launch providers are classified under both *space* manufacturing (assembly of launch vehicles) and operations (control of launch vehicles). Additionally, operators and service providers offer *space* applications.

***** 'Earnings Before Interest and Taxes' (EBIT) margins are profitability indicators, which show a company's or sector's earnings before interest and tax as a percentage of its net sales (OECD, 2012:44).

Source: Satellite Production Projects.

The sub-sectors do not only differ in their profitability, but also the temporality of their revenue streams, as they capture value from their satellite production projects at different moments in time. The outcome is a complex industry structure, with multiple entry and exit points. There are three conceptual models that have been blended to frame the analysis of the industry's structure: (i) PPT (Bryson, 2008); (ii) netchain (Coe *et al.*, 2008; Lazzarini *et al.*, 2001); and (iii) texture (Fineman and Hosking, 1990; Cooper and Fox,

1990) (Section 2.4.1). The outcome of this blending is an approach which focusses on production projects and their associated tasks, rather than solely manufacturing or services activities. It also explores the "various form of backward and forward linkages" between production projects and considers the impact of their contextual framework (Bryson, 2009:42).

The conceptual framework's approach to understanding organisation was to identify a series of production projects (PPT approach) (Bryson, 2008), explore the links between them (netchain literature) (Coe *et al.,* 2008; Lazzarini *et al*., 2001), and outline when and how they are influenced by the industry's contextual framework (texture approach) (Fineman and Hosking, 1990; Cooper and Fox, 1990).

The remaining sub-sections explore the value creation and geography of manufacturing, operation and application production projects, whilst also considering their vertical ties and any interdependency between them.

4.2.2 *Space* Manufacturing

Space manufacturing production projects encompass a broad range of tasks related to "the manufacture and delivery of components that go into the Earth's orbit or beyond" (Harrison, 2012:183). It is the "*traditional part of the sector making low numbers of high value products which are easily identified and lobbed into space*" (GovFacilitator1b). These high value *space* products include launch vehicles, satellites, user ground equipment and terminals. In the UK (2012/13), the breakdown in turnover between these manufacturing segments is as follows: £60 million (7%) on launch vehicles and subsystems; £528 million (58%) on satellite platforms/payloads; and £143 million (16%) on ground equipment. There is also an additional £167 million (18%) resulting from research and consultancy and £9 million of turnover which is undefined (London Economics, 2015). This means that the primary product focus (production projects) for UK *space* manufacturers is the production of satellites, with less attention being placed on launch vehicles, subsystems and ground equipment. Launch vehicle investment efforts are particularly low due to the absence of a launch site in the UK (Section 4.5).

Satellite manufacturing productions projects are managed by main or chief contractors, known as 'primes'. Primes are contracted by satellite operators or intuitional customers and are responsible for designing the satellite, dividing tasks and managing the final integration of components. There are only a small number of large primes in the market, only four of which are based in Europe, of which only one assembles satellites in the UK (L.Prime1a) (Qi3, 2012). L.Prime1's focus is on the more *"traditional space market"* (i.e. *space* transportation, large satellites and ground systems), whilst an additional two UK prime manufacturers (L.Prime1a and M.Prime2a) focus on *"small satellite missions and services"* (Billing, 2013).

Once a prime has designed a satellite, the first task is for it to decide whether to vertically integrate all of the project's production tasks or subcontract some out externally. This decision will be impacted by the internal resources that are accessible to the firm and also its routines (which are influenced by path dependency). Tasks are internal activities in a firm; if tasks are outsourced to other firms they become subordinate projects and are governed by BSRs. The subordinate projects manufacture one or more of the satellite's components; they are managed by primary sub-contractors who may also outsource particular tasks to secondary sub-contractors (and so on) (see Figure 4.2). Some components are niche and specialised for particular projects, whereas others are more standardised and may adopt a ‘build to print’ approach (Billing, 2013). There are also ‘intermediate’ service tasks which may be outsourced such as accountancy and legal advice (Bryson, 2008). The distinction between production projects and subordinate projects is a new contribution to the PPT literature and helpful for identifying when production projects involve more than one firm.

Production Project: Satellite Manufacturing
(Design the satellite, divide tasks and manage the final integration of the components).
Prime Manufacturer:
- Internal Tasks:
- Internal Resources
- Routines
- External Tasks (linked by BSRs)

Subordinate Projects
(Manufacture larger components such as, the satellite’s platform and/or payload).
Primary Sub-contractors
- Tasks
- Internal Resources
- Routines
- External Tasks (linked by BSRs)

Subordinate Projects
(Manufacturer smaller components such as, batteries and antennae).
Secondary Sub-contractors
- Tasks
- Internal Resources
- Routines
- External Tasks (linked by BSRs)

Subordinate Projects
(Manufacturer standardised materials such as sheet metal).
Tertiary Sub-contractors
- Tasks
- Internal Resources
- Routines
- External Tasks (linked by BSRS)

Further Subordinate Projects

Figure 4.2: Subordinate projects and tasks involved in satellite production projects.

Source: Author.

The most important components of a satellite are the 'platform' and 'payload', which can be manufactured separately as two subordinate projects. A satellite's platform or "*space*craft bus" is the physical structure which holds everything together and keeps the satellite "up there and in the right place" (Billing, 2013:25). It contains the support subsystems, which control the altitude, propulsion, temperature range and power supply (provided by solar panels and batteries, also on the platform) (JSAT International, 2014). The payload is the 'business-end' of the satellite, or the part "which is actually earning the money" and contains a repeater (processes/transmits the signals from and to the ground), and an antenna (reflects the signal and creates the footprint) (JSAT International, 2014; Billing, 2013:25). The payload is dependent on the platform to ensure it is pointed in the right direction; is operable; is in the correct orbit and has the requisite power supply. Therefore, a satellite platform is "supplied to consumers as a vehicle" for accessing a service through the payload (Bryson, 2009:34). This is an example of 'service encapsulation' and illustrates the interdependency between services and manufacturing, since the manufactured hardware (the platform) has no value without the service (the payload), and the service delivery (payload) is dependent upon the hardware (the platform) (Bryson, 2009). In some projects, the prime manufacturers neither manufacturer the platform nor payload, but instead "*just integrate the components*" during final assembly (M.Prime1a). In other projects, the prime will produce the platform and/or the payload, which "*as well as using internally"* it will also *"sell externall*y" (L.Prime1d).

For L.Prime1, its manufacturing process is fragmented, as different stages of production are divided between separate sites in Portsmouth (UK), Stevenage (UK) and Toulouse (France):

> *"So you can be working on one part of the spacecraft in Portsmouth, somebody else could be working on the bit that your part fits to on the spacecraft in Stevenage and then someone is working on the power system in Toulouse and feeds the structure that the guys in Portsmouth are designing on the computer system"* (L.Prime1d).

In contrast, the production process of the smaller primes is less fragmented, for instance, 90% of what L.Prime2 "*…do is based in Guildford*" (L.Prime2c). Any manufacturing and assembly takes place in a specially constructed 'cleanroom', which has a controlled environment to minimise contamination (CAT, 2013). All four large primes' supply chain of components and subsystems is "*huge*" and "*global*", but is concentrated across "*…the US, Europe, Russia, Japan and India"* (GovPolic2b; L.Prime2c). These relationships are important because the manufacturers recognise that they are not "*the best at doing everything*" and it is necessary to use external suppliers when they have greater competencies (M-Prime2a). For example, "*it's almost impossible to build a satellite without using some US technology*", yet the largest UK-based prime prefers to "*buy in Europe*", so that in its satellites, "*90% plus would be the Europe bit*" (L.Prime2c). This is partly due to trade regulations which restrict UK primes from buying from certain countries because of political conflicts and concerns around defence. For example, they "*…don't do business with China or any similar, and obviously Russia is becoming a bit of a struggle*" (M-Prime2a). These restrictions are exacerbated in instances where manufacturers are contracted to produce a defence satellite, as "*…there are sensitive things that would have to be done in the UK*" (L.Prime2c).

There is a relatively small market for satellites globally (twenty to twenty-five contracts awarded annually, with only ten in Europe) and thus, a prime typically only wins contracts for two to five satellites a year. The limited demand for satellite products means that the *space* market is cyclic, with fluctuations in procurement (Billing, 2013). This is particularly challenging for suppliers of components, as it creates significant time-delays between sales, thus reducing revenue streams, availability of work for employees and cash flow for infrastructure improvements (Billing, 2013). These issues place considerable pressure on subcontractors to produce multipurpose components, which can be sold across other sectors. Consequently, 56% of UK satellite manufacturers are 'generalist', meaning that alongside the *space* sector, they manufacture other products (such as military aircraft and security systems) that target other industries and user needs (Billing, 2013). This diversification impacts on the satellite manufacturers' sources of competitiveness, as it maximises market opportunities and sustains revenue streams (Wan *et al*, 2011). Similarly, there are companies outside the *space* sector which "spacify" their products and target satellite projects (Billing, 2013:30). This interaction between the *space* sector and other sectors affects how we characterise it, whereby rather than being niche and detached, there is evidence of it being 'foundational' and playing a central role in the economy (Tremblay and Tremblay, 2007). This evidence includes the direct impacts from satellite-enabled applications, as well as the inevitable spillover effects from satellite technologies on other industries, as firms switch between different markets.

In light of a lengthy period of design, manufacture and assembly, a typical satellite project takes five years from the beginning of design to final launch (Fortescue, 2003:11; L.Prime2a). This is largely attributed to the distinctive engineering challenges posed by the 'hostile' outer *space* environment (MOD, 2010:1; London Economics, 2015). Outer *space* is 'hostile' because, without the effects of gravity and the protective shield from the Earth's atmosphere, it is a near-vacuum, posing a significant threat of radiation, solar particles and extreme temperatures (120°C to -100°C) (MOD, 2010). Additionally, there is intense pressure caused by the "high levels of vibration" during launch (Fortescue, 2003:12). *Space* debris also presents a threat (Jakhu and Pelton, 2014). Debris or '*space* junk' is created by collisions between *space* objects (i.e. defunct satellites), which continue to multiply in a chain reaction known as the Kessler syndrome:

> "*So if two spacecraft smash into each other, they break into two bits, so that's four bits and then break up again, you can very quickly prove that the rings of Saturn are made up of space debris*" (GovPolicy2b).

The levels of debris in low-Earth orbit are so high that "*the International Space Station regularly has to make manoeuvres to avoid it*" (GovPolicy2b). Due to these 'threats' in *space*, there is value in research laboratories and consultancy firms investigating "the challenges of launch conditions and orbit environments", and developing solutions for manufacturers on how to resist them (Billing, 2013:30). Consequently, research and consultancy captures a significant proportion of the turnover generated by the UK *space* sector (£167 million, or 18%) (London Economics, 2015).

The financial risk of launching a satellite into orbit depends upon the size of the satellite, since they range from "*expensive assets weighing over 4,000kg, to things that will fit in the palm of your hand*" (GovDefence1b). For example, cubesats are "miniaturized satellites measuring 10x10x10 centimetres and weighing 1 kilogram", whereas extra-heavy satellites weigh over 5,400kg (Table 4.1) (FAA, 2013:69; Anderson *et al*., 2014). A smaller satellite takes less time to develop and costs less money to build and launch, thus the financial risks in respect of launching them are lower than for launching larger satellites. However, given that they have less capacity and are not as durable as larger satellites, smaller satellites have shorter lifetimes. Therefore, between 2004 and 2012, the average weight of satellites launched globally remained over 4,000 kilograms and despite an increasing rise in the number of lighter satellites, heavier satellites have since continued to dominate the market (48% in 2013). This is significant, as it has meant the *space* sector has continued to be relatively conservative and risk averse, impacting on the organisation of production and source of competitiveness.

Table 4.1: A Weight Comparison of Different Satellites in Orbit.

Class	**Weight**
Extra Heavy	> 5,400kg
Heavy	4,200-5,400kg
Intermediate	2,500-4,200kg
Medium	2,500-500kg
Small	500-100kg
Micro	100-10kg
Nano	10-1kg
Pico	< 1kg

Source: Anderson *et al*. (2014); FAA (2013).

The class and weight of a satellite is determined by the type of customer. Satellite manufacturers have "*a varied customer base*"; but given that the majority of customers are commercial operators and government agencies, they tend not to "*deal directly with the consumer"* (M.Prime2). All customers have different needs, which may influence the class of satellite required. For example, a commercial telecommunications operator may demand an extra-heavy telecoms satellite, whereas a government agency is more likely to buy a small observation satellite. The satellites are "*customised to suit different mission types*" and, unlike other manufacturing industries where products can be standardised, they are "*not generic*" (L.Prime1d). The extent to which satellites are bespoke depends upon their intended purpose. For example, observation satellites vary considerably depending on whether they are "*assessing ice caps*", "*looking at magnetic fields around the Earth*", "*monitoring solar winds*" or used for other missions (L.Prime1d). Meanwhile, communication satellites are more standardised; whilst alterations are made to their payloads, their platforms remain constant as a standard frame. To one of the research participants:

> *"…it's a bit like buying a Ford focus - you choose a standard design and then get to add the extras to make it yours"* (L.Prime1a).

Since manufacturers rely on the custom of operators' and operators on the manufacturers' products, there is a mutual dependence between *space* manufacturing and satellite operations. Consequently, when conceptualising the *space* industry, it is important not to isolate manufacturing from service provision, despite the differences between their production projects. This provides empirical evidence as to the importance of considering both manufacturing functions and product related services in an industry study, as they are part of integrated production projects (Bryson, 2008). Additionally, it highlights the relevance of the netchains and texture models to the analysis because of the interaction between the vertical layers within the industry (i.e. *space* manufacturing and satellite operations) (Lazzarini *et al*, 2001; Cooper and Fox, 1990). The specific role of satellite operators will now be explored.

4.2.3 Satellite Operations

Satellite operators finance "a satellite's construction and launch" and sell communication bandwidth, positioning signals or Earth observation data to their customers (OECD, 2012:44; Gershon, 2009:184). In the UK, this sector is larger than *space* manufacturing, whereby in 2012/13 it contributed £546 million more in turnover to the UK economy (London Economics, 2015). Satellite operating production projects also involve controlling the satellite's 'spaceflight' and the payloads in external or internal ground stations. Managing the spaceflight involves controlling the position in orbit and the on-board systems (i.e. power supply, thermal control, communications), whilst managing the payload requires control of the sensors, position of antennas, communication channels and signal transmissions (MOD, 2010). Some operators do not have the resources to control their own satellites and therefore subcontract the management of their spaceflight and payload to other operators. As with the manufacturing production project, the thesis identifies these outsourced tasks as subordinate projects. There are also instances where operators lease transponder capacity (part of a payload) from a competitor's satellite to supplement their own satellite fleet. This is common in the telecommunications sector, as each satellite covers "a specific geographic region, or 'footprint', thus helping the operator address specific customer markets" (OECD, 2012:44). Therefore, if an operator does not have a satellite with the appropriate footprint to meet a customer's needs, it has to lease capacity from a competitor's satellite. Depending on the operating arrangement [(i) own and control the satellite; (ii) own or control the satellite; and (iii) lease transponder capacity], there are varying power-dynamics (Chapter 6).

The organisation and sources of competitiveness of the satellite operators vary depending on the target market of their projects, namely: telecommunications, Earth observation, or navigation. In the UK, telecommunications (i.e. broadcasting and satellite communications) contributes the highest proportion of sector turnover (82%). The telecommunications market is highly concentrated, since the top four global operators (all with a UK presence) account for 60% of the worldwide telecommunications revenues (UK Space Agency, 2014). In contrast, the market for Earth observation data (1%) and navigation (8%) is much less mature, since satellites in those markets have traditionally been "owned and operated by governments" (Grimard, 2012). This is due to the high costs of contracting and launching a satellite (on average $350 million) and smaller market size (compared to telecommunications), which has locked out commercial actors and left government actors to dominate. However, this trend is starting to shift, with the development of smaller satellites and low-cost launchers, which are reducing costs significantly and making observation missions more commercially viable (navigation remains government controlled). It also means that *space* has become more accessible for less developed nations, with fifty countries (for example, Azerbaijan, Ecuador, Malaysia, Nigeria, Algeria etc.) outside of 'established *space* nations' expected to launch "twice the number of satellites they did in the past 10 years" by 2024 (Euroconsult, 2015). The emergence of these new players has increased the competition for UK satellite operators.

When interacting with their customers, satellite operators offer a range of service level agreements and either deal with the consumers directly (business-to-consumer), or, more commonly, use "*a network of resellers around the world*" (business-to-business) (GovFacilitator2b). Resellers, otherwise known as 'consolidators' or 'market intermediaries', package satellite capacity and data into a single product, which they then sell onto customers (Palmer and Quinn, 2003; Barrett, 1998). The advantage of using resellers is that it provides the operators with the necessary "*reach to access global markets*", since the resellers often know the markets "*best*" and are more equipped to serve the end-users (GovFacilitator2b; M.Operator1a). For example, an oil and gas customer would need an "*overall service*" from their supplier, who could offer "*offshore* *maintenance at very short notice*". This requirement would be too "*specialised*" for a satellite operator, hence why they sell their "*bandwidth to an integrator who will bundle all those things together*" (S.Operator2c). When dealing directly with the customer, the service agreements cover everything from long-term leases (from monthly to life-time contracts) and transponder sales, to occasional use, where the customer is not committed to a 'recurring service' but "an as-needed basis" (Gershon, 2009:186). This varies between satellites and therefore operators, depending on the functional requirements. For example, one operator "*might have agreements to provide regular down links to a customer's site*", whereas another may be contracted "*to provide imagery over certain geographical areas within a certain time*" (L.Prime2c). The frequency of services depends on the external environment, such as the "*issue of cloud cover*" affecting observation images (GovFacilitator2b).

The operators also address different markets by covering "specific geographic regions or footprints" with several satellites (OECD, 2012:17). Traditionally, these markets would be defined by a particular scalar region and categorised as one of the following: (i) international satellite organisations; (ii) regional satellite systems; (iii) national satellite systems; and (iv) private separate satellite systems (OECD, 2012). However, technological and market developments have redefined these "formerly distinct markets", so that operators now offer services across different geographical scales (OECD, 2012:17). For instance, "*in the old days, a European provider would simply offer coverage over their area, but they have all tried to grow into global entities*" (M.Operator1a). Consequently, all eleven commercial operators registered in the UK (Table 4.2) have developed at least regional satellite systems, if not international.

Table 4.2: The Number of Satellites Registered to each UK Organisation.

Organisation	Number of satellites registered
Government	**14**
Ministry of Defence	13
UK Space Agency	1
Research Institutions	**9**
Science and Engineering Research Council	3
University of Surrey (before SSTL)	4
Space debt, Arthur. C Clarke Building	2
Commercial Operators	**69**
Surrey Satellite Technology Ltd	17
British Aero*space Space* Systems Ltd	1
Europe*Star Ltd	1
Space debt, Arthur C Clarke Building	2
ICO Global Communications Ltd	2
Inmarsat	12
Qinetiq Ltd	1
SES Global Satellite Leasing Limited	15
Paradigm Secure Communications Ltd	4
Avanti Communications Group plc	3
03B Limited	4
British satellite broadcasting ltd (Have since merged with Sky)	2
Intelsat	3
Telenor (UK) ltd	2

Source: Author. Analysis of UK Registry of Outer *Space* Objects (1969-2014).

Due to the large scale of their satellite systems, operators have offices across the globe. However, there is a precise geography to these office locations, as they target specific markets along certain lines of longitude and latitude, which correspond to the footprints of the satellites. For example, S.Operator2 has offices in "*Dubai, Singapore, Jersey, London, the Hague, Washington DC and Rio*" (S.Operator2b). These are locations chosen strategically to enable it to manage its target markets. Target markets are determined by "*where is the biggest demand, so where are most people looking to use satellites*" (S.Operator3c). For example, in the telecommunications segment, Latin America and Africa present a key market opportunity because of their "*high growth*" and dependency on satellite communications, since "*terrestrial links are not good*" (M.Operator1a).

In addition to market hubs, there are other factors which can influence the geography of satellite operations. For instance, in the UK, nine out of eleven of the commercial operators have offices in London because, traditionally, it was important to be "*near to the BT tower… the hub of the broadcasting industry"*, as connection costs increased with the distance away from it (L.VSATApplications1a). This cost advantage has since become redundant, as fibre optics have become cheaper and more readily available, so from 2006-7 the BT tower's thirty-eight communications antenna dishes were switched off because they were "superseded by fibre optic technology" (BT, 2011). However, the commercial operators have "*remained in London because once you get lots of fibre lines into your building, it's quite difficult to move them*" (L.VSATApplications1a). This is an example of path-dependency caused by sunk cost, which impacts upon the organisation of production and competitiveness of the industry (Clark and Wrigley, 1995; Martin and Sunley, 2006).

Furthermore, location decisions are influenced by proximity to satellite application providers, who purchase data and bandwidth from the operators and resell to end-users. Similar to the mutual dependence between *space* manufacturing and *space* operations, this spatial relationship reflects interdependency between satellite operators and satellite application providers. This highlights how it is important to not just consider service actors who have direct relationships with the manufacturers, as there can be service actors who only interact with other service actors. For instance, satellite application firms interact with the service operators rather than the manufacturers of the satellites. The role of the satellite application providers is discussed in the next section.

4.2.4 Satellite Applications

The satellite applications sector constitutes the supply of *space*-enabled services and accounts for the largest proportion of UK *space* turnover (78% in 2012/13) (London Economics, 2015). It is made up of three core segments, namely Direct-To-Home (DTH) provision, receiver equipment supply and value-added services provision, and is dependent on the broadcasting or data content provided by satellite operators. DTH providers are the biggest players in the applications market (65.7% of UK *space* applications turnover), and are responsible for distributing television signals to small dishes and satellite receivers (London Economics, 2015). The DTH providers lease payload capacity (transponders) from satellite operators and then broadcast their channels directly to end-users or sell them to their competitors at "*a wholesale rate of 65% to 70% of the cost*" (L.DTHApplications2a). They "*get 12 channels in one transponder, HD broadcasting is about half that and on each satellite there are about 30 transponders*" (L.DTHApplications2a). In addition to the end-user contracts and wholesale channel agreements, there is a further revenue stream created by broadcasting externally-owned TV channels. For example, one of the smaller DTH providers broadcasts channels for religious institutions and political campaigners "*who want to deliver messages*" and increase their public profile and influence (Mi.DTHApplications1).

The value-added services segment is smaller than DTH (8% of turnover in 2012/13), but still critical to the global economy, as it adds value to raw observation data through "*management and analytics*" and transforms that data into a usable information service (GovPolicy3d; S.SystemsManufacturer1a). The providers of value-added services differ from data resellers, as the former "*crafts the data into something else"* and delivers a 'functional result', as opposed to a 'pre-determined product' (M.Applications1b; Bryson, 2009:20). These 'information services' are used to support a range of environmental activities, including "*resource monitoring*" (of land, agriculture, forests etc.), "*fire hot-spot detection*" and "*sea-surface parameter/temperature monitoring"* (L.Prime1c; Mi.DataApplications2c). Additionally, there are "*civil applications*" used by local planning offices for monitoring urban change and "*industry specific applications*" which respond to needs across a broad range of sectors (S.SystemsManufacturer1a; CGI, 2014). For example, there are satellite applications which monitor the "*levels in oil storage tanks*" and those which direct fishing companies to where ice has melted *"so they can catch their fish"* (L.Insurer2a; Mi.DataApplications2c). These value-added services are a more affordable option than purchasing the complete raw data set, as the user can simply request the "*little chunk of data*" they require (GovFacilitator2d). These 'little chunks of data' can then be processed and used as a service or exchanged as a commercial product to capture different forms of value.

The value-added services are delivered by established satellites firms (such as existing operators with subsidiaries) and small start-ups addressing niche markets (Vargo *et al*., 2008; Appadurai, 1994; Marx and Ryazanskaya, 1963; Grimard, 2012). In the case of start-ups, they are often distanced from the operation and use of *space* technology. For example, if you "*talk to Tomtom they wouldn't think of themselves as a space company and yet they use GPS satellites all of the time"* (GovPolicy3d). As a result, the "*space-based nature*" of the economic agents involved in the satellite industry becomes "*hazier*" as you move along the production project, away from *space* manufacturing and operations (GovPolicy3f). Nevertheless, the reliance of these service providers on satellite data means they are part of the same "web of interacting elements" that is the *space* sector (Fineman and Hosking, 1990:574).

The service providers source the raw data from commercial resellers or government agencies. Resellers charge up to "*£1000 an image"*, whereas government data can be free in instances where policy dictates that since "*tax payers have already paid for it, it should be made available"* (Mi.DataApplications2a). This data is accessed directly or through "*web-based applications which enable users to look for and then select satellite data for their needs*" (Mi.DataApplications1a). These applications are similar to "*travel comparison websites*" and generate income by "*getting a cut of any of the sales*" (Mi.DataApplications1a). Sourcing the data through these websites is significant, as it can mean that the service providers are "*completely unaware of where the data came from*", resulting in a disconnection between the satellite infrastructure and end-users (GovFacilitator2b). On the plus side, it also means that that data can be accessed "*pretty much anywhere*" and that the value-added service providers are not restricted to certain locations, unlike *space* manufacturers and operators (Mi.DataApplications1a).

In order to access DTH signals and value-added services, users often require appropriate receiver equipment, the supply of which contributes a further £236 million in turnover annually (2012/13) (London Economics, 2015). This equipment is only necessary for applications where the user is receiving a broadcast signal or raw data directly (which is later processed) and "*actually wants to use the satellite network"* (L.Operator1b). Application providers typically outsource the production and installation of dishes or receivers to manufacturers and other subcontractors. The largest UK DTH provider is an exception to this, since they have vertically integrated the manufacturing tasks:

> *"…with the set top boxes, we started out letting that out to* [Subcontractor 1] *and others to make the boxes, we then brought them* [Subcontractor1] *and consolidated and did our own manufacturing, so now our set top boxes are all made in China, but designed here. So it's just acquiring a downstream part of the business in order to improve margins and keep our costs down"* (L.DTHApplications2).

Therefore, there is evidence of vertical ties between satellite applications (DTH signals or value added-services) and *space* manufacturing (production of receiver equipment).

4.2.5 Section Overview: The Structure of the *Space* Sector

This section separated the analysis of the structure of different sectors of the *space* sector and was effective in highlighting the distinctive roles, characteristics and spatial distributions of *space* manufacturing, satellite operating and the provision of satellite applications. In light of their differences 'on paper', these three sub-sectors could be described as separate industries. Nevertheless, the influence of the netchains literature on the conceptual approach meant that vertical ties (transactions between projects) as well as horizontal ties (transactions within projects) were explored (Lazzarini *et al*, 2001; Coe *et al.*, 2008). This analysis of the interactions between the three sectors found that the operators and service providers are dependent on the manufacturer's satellites and receiver equipment, whilst the manufacturers rely on purchasing by the operators and service providers. Therefore, they are not separate industries, but part of the same "web of interacting elements" (Fineman and Hosking, 1990:574). This interdependency provides empirical evidence on the importance of considering both manufacturing and service functions in an industry study (Bryson, 2008).

Interactions were also found to exist between the satellite agents and other industries; satellite manufacturers generalise their products to target other sectors and satellite-enabled applications are used in a range of sectors (including agriculture, energy and TV broadcasting). These interactions mean there are inevitable spillovers from satellite technologies into other industries, resulting in external influences, impacting on the governance, organisation and competitiveness of the *space* sector. This finding was significant as it proved the *space* sector to be 'foundational' and a key player in the economy, rather than being niche and detached (Tremblay and Tremblay, 2007). Additionally, it encourages economic geographers to avoid isolating the impacts and character of their research industries from the influences of surrounding sectors.

Currently, the PPT framework and netchain layering model have been applied to the chapter to analyse horizontal (transactions in the same layer) and vertical (transactions between layers) ties within the UK *space* sector. However, this provides a partial understanding of the *space* sector, as it is yet to explore external factors that impact on the interdependent production projects (referred to as the contextual framework) (Cooper and Fox, 1990). The subsequent sections address this gap and, in doing so, present a 'texture' model of the *space* sector (Fineman and Hosking, 1990; Cooper and Fox, 1990). First, satellite operators (and consequently the manufacturers and service providers) are dependent on the availability of orbital slots and frequency spectrum in *space*. Therefore, the geography of these *space* locations is to be explored. Second, there is critical ground infrastructure (i.e. Earth stations and launch sites), which facilitates satellite projects that also needs to be spatially located and understood.

4.3 The *Space* Geography of the *Space* Sector

The factors which influence the geography of economic activity and the comparative advantages of different locations (both local and global) have been discussed extensively across the economic geography literature (Fujita *et al*., 1999; Dicken, 2003; Mudambi, 2008). The geography of economic activity in *space* however, has been overlooked. This is important to address, since the location of satellites in *space* is an external factor that impacts on production projects and a necessary part of addressing the second research objective: to introduce orbital slots and frequency spectrum as competitive resources.

The location of satellites is determined by their orbits, which vary according to the satellite's purpose, target market on Earth and availability of spectrum (frequencies used to transmit signals to and from Earth) (Figure 4.1). There are three key orbits (Low Earth Orbit, Medium Earth Orbit, High Earth or Geostationary Orbit), which have unique advantages and disadvantages and are appropriate for different roles (see Table 4.3). For instance, the altitude and inclination (angle) of the orbit determines the 'terrestrial footprint' (the coverage area on Earth that the satellite can 'see'), in that the higher the altitude, the larger the footprint, which is important for TV broadcasting (Riebeek, 2009, MOD, 2010). Similarly, the lower the orbit, the lower the latency (time delay between input into the operating system and output by the satellite), which is valuable for mobile communications.

Table 4.3: The Characteristics and Roles of Satellite Orbits.

Name (initials)	Altitude (km above Earth's surface)	Characteristics: Advantages	Characteristics: Disadvantages	Roles
Low Earth Orbit (LEO)	100-1200	Close to the Earth's surface so: - Less energy is needed to launch a satellite. - Low latency (time delay between input into the operating system and output by the satellite). - High-resolution images (Fortescue *et al*, 2003). A 100km polar orbit is 'sun-synchronous'. This means that the satellite passes over the same points, at the same local time each day. This creates a consistent angle of sunlight, which allows images in the same season to be compared between years (MOD, 2010).	Close to Earth's surface so satellites: - Have a relatively limited 'perspective' or terrestrial footprint (MOD, 2010). - Are dependent on multiple ground stations, as LEO satellites have fast flight times and pass over different ground stations intermittently (MOD, 2010). - Are affected by atmospheric drag and high levels of debris-shortening average lifetime of satellites to 7 years (MOD, 2010).	Common amongst smaller, lower capacity satellites, such as cubesats (the lower cost of LEO launches compliments low-cost satellite models). High resolution and sun-synchronous capabilities make it an attractive orbit for Earth observation imaging. The low latency provision is also valuable for mobile communications.
Medium Earth Orbit (MEO)	1200-35786	A higher altitude than LEO, so the satellites in this orbit have a larger terrestrial footprint (MOD, 2010: 1-47)	The satellites are moving relative to the Earth so, as with LEO, tracking them requires the use of multiple ground stations, which increases costs.	The consistent and predictable nature of the semi-synchronous orbit is used by GPS satellites.

		A semi-synchronous orbit (20,200km) passes over the same two points on the equator each day, thus is consistent and predictable (Riebeek, 2009).	Satellites are at risk to radiation damage caused by the 'Outer Van Allen belt' (8400-36,000km), a "collection of charged particles, gathered in place by Earth's magnetic field" (NASA, 2014).	Also a location for telecommunication satellites, as still has a lower latency than GEO.
High Earth Orbit or Geostationary Orbit (GEO)	35786	A 30km wide belt in which satellites travel at the same speed relative to the Earth's rotation (are geo-synchronous), making them a "stable target" for ground stations on Earth (providing full-time coverage) and avoiding costs associated with tracking (Warf, 2006:386; Copiz, 2001). The higher altitude enables a coverage area as large as 42% of the Earth's surface, so only three GEO satellites would be needed to provide global coverage (Collis, 2009; Warf, 2006:386).	The distance from the Earth causes: - High latency - High launch costs as more energy is required to reach the distance. Since GEI is positioned over the equator, it cannot provide coverage of polar regions. There are a limited number of GEO orbital slots.	The stationary position is attractive for DTH broadcasters and weather forecasters, who rely on full-time coverage and not incurring the cost of having to track the satellites (Fortescue *et al*, 2003).

Source: Author.

Whilst *space* is a vast area, the locations of satellites are limited to the "*finite*" number of orbital slots (GAO, 2011; Rhys Morgan, Intelsat). This limit applies to the 30km-wide geostationary orbit, which has only 1800 available slots when GEO satellites are safely distanced apart (two degrees or 1000km apart, in order to avoid collisions and interference) (Copiz, 2001; Collis, 2009). This is significant because the telecommunications sector relies on the geosynchronous advantages of the GEO, which because of its limits has become "increasingly crowded" around slots where the terrestrial footprint covers target markets (both established and emerging) (Warf, 2007:388). Consequently, telecommunications operators are faced with the challenge of "finding parking spaces" for their satellites in locations where the majority of the slots have already "*been gobbled up*" (Thompson, 1996:280; S.Operator3a). They are like "*gold dust*", meaning that allocation of a slot to one operator 'thwarts' its competitor's attempts to compete, presenting what is known as a 'first-mover advantage' (FMA) (GAO, 2011; Finney *et al.*, 2008). It is different for the lower Earth and medium Earth orbits (non-geostationary), since the satellites are not in a fixed position relative to the Earth's rotation. Therefore, non-geostationary operators file *"for an altitude or an inclination, which defines the orbital parameters of where the satellite will be"*, it is not a 'fixed' orbital slot (S.Operator2a).

The finite number of geostationary orbital slots means that they have to be managed and assigned by a United Nations specialised agency, the 'International Telecommunications Union' (ITU). The ITU also allocates the portion of radio frequency spectrum the geostationary and non-geostationary operators use to communicate between the satellite and ground stations. The process for applying for geostationary slots and frequency spectrum begins three to five years prior to the launch of a satellite and is overseen by the ITU. There are three steps:

(i) Advance Publication of Information (API): the operator delivers “a general description of the proposed satellite network” to other government administrations and allows them to “assess the potential impact of a proposed satellite deployment on existing or planned satellite networks” (Gershon, 2009:187). The administrations are then under an obligation to provide their comments and reactions within four months which, depending on disputes, may cause a change to the intended frequency.

(ii) Coordination Process: the operator “must approach the incumbent and obtain its agreement regarding the potential for interference” (Gershon, 2009:188). They then evaluate the proposed network and inform the filing administrator as to whether they agree. The “basic criteria for acceptable interference levels are set by the ITU” (Gershon, 2009:188).

(iii) Notification of frequency assignment: after “the coordination of frequencies has been fully resolved”, the Radio Regulations Board (RRB) “will record the assignments in a master register” (Gershon, 2009:188). This frees the operator to appoint a manufacturer and later launch its satellite.

Not all frequency spectrum is useful, but that which can be used and coordinated is divided into six frequency bands (Table 4.4). These bands have each been assigned to particular services in order to avoid interference. For example, X-band is dedicated to “*access* for *the military”*, where *“civilian operators cannot operate”* (GovDefence1b). Like orbits, different spectrum bands have unique properties, which make them appropriate for “*addressing different applications and different markets*” (S.Operator3c). For example, “lower frequencies (L-, S- and C-Bands) are less affected by the heavy rainfall in parts of Africa/Asia/Latin America” and therefore can serve these markets (ESOA, 2010).

Similarly, "higher frequencies (Ku- and Ka-Bands) allow smaller antennas to be used on the ground", which are necessary for DTH applications (ESOA, 2010).

Table 4.4: Satellite Frequency Bands.

Name	**Frequency (Ghz)**	**Services**
L-band	1-2	Global Position Systems (GPS) and satellite mobile.
S-band	2-4	Weather radar, surface ship radar and some communications satellites.
C-band	4-8	Satellite communications (full-time satellite TV networks or raw satellite feeds). Used in areas subject to tropical rainfall, as less susceptible to 'rain-fade'.
X-band	8-12	Civil, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, defence tracking and vehicle speed detection for law enforcement.
Ku-band	12-18	Satellite communications (10.7 Ghz- 12.75GHz = Europe DTH broadcasters).
Ka-band	26-40	Satellite communications (27.5 GHz- 31 GHz) + high-resolution, close range targeting radars on military aircraft.

Source: Author. Data from: ESA (2013).

Individual operators use separate frequencies within the spectrum bands which, like orbital slots, are "*a limited resource*", with associated first-mover advantages (S.Operatator2a; S.Operatator2c). However, the "*fight for spectrum*" is particularly challenging, since the competition does not just involve "o*ther space operators, but other users of the spectrum more widely, so the mobile community for instance*" (GovPolicy3b). This once again highlights the interaction between *space* and other sectors, as well as the challenge in identifying all of the spillover effects and influences which impact upon governance, organisation and competitiveness.

This section has explored why "*without spectrum and orbital slots you can't move forward*" in the *space* sector (S.Operatator2a). This is because they are key resources upon which the operators and value-added service providers depend. Therefore, they are an integral part of any satellite production project and a unique characteristic of the *space* sector, which should be understood and taken into consideration when exploring governance, organisation of production and competitiveness. There is also a 'grounded' part to the geographical context of the *space* sector. This includes the ground stations and launch sites, which are discussed in the next section.

4.4 The *Space* Sector's Ground Geography

When explaining the spatial distribution of economic activity, 'traditional neoclassical' theorists applied the 'first-nature geography' principle (Redding, 2010; Brülhart, 1998; Diamond, 1997; and Sachs, 2005). First nature geography comprises of the natural advantages of a location, particularly in respect of its resources and geographical position (influencing the local climate and topology) (Krugman, 1993; Fujita and Mori, 2005; Zubarevich, 2009). Sheppard (2011:46) described it as the "physical geographic blackcloth" of a site, which "profoundly shapes the conditions of possibility" for particular economic activities. However, the economic geography literature has since acknowledged the "many cases" where economic centres have developed in locations "without obvious natural advantages" (Schmutzler, 1999:356). Consequently, 'second-nature geography' has emerged and become popularised across the economic geography literature.

Second-nature geography deals with the advantages of a location that are ‘endogenous’ to physical factors and instead relate to the “interaction between economic agents” (Crafts and Wolf, 2014:1109; Venables, 2006:10). These economic agents include other firms, educational institutions, financers, trade associations, innovation centres and government agencies (Keeble, 1999). They present location-specific advantages, since through interaction and sharing a common purpose with economic agents, firms can develop an “ensemble” of specific assets, including knowledge and skills (Kitson *et al.*, 2005:994; Coe *et al.*, 2004). These assets encourage growth. The interaction with the “supportive organizations and institutions” has been identified as regional ‘institutional thickness’ and is associated with ‘spatial clusters’ or situations where there is a proximity of interconnected companies, specialist suppliers and service providers (Coulson and Ferrario, 2007; Thrift, 1994; Cooke and Morgan, 1993; Keeble, 1999; Porter, 2000).

Second-nature geography theories, such as institutional thickness and spatial clusters, dominate the recent economic geography literature on the spatial distribution of industries (Jenkins and Tallman, 2015; Rantisi, 2014; Delegado *et al.*, 2014; Lorenzen and Mudambi, 2012). Nevertheless, there are industries where first-nature geography remains important. The oil and gas industry for example, depends on the natural resources of sites (Priest, 2007). Similarly, alongside economic relationships, first-nature factors influence the spatial distribution of the *space* sector, as the locations of launch sites and ground stations are governed by the natural advantages found at particular geographical positions. Therefore, “*in the same way you have the orbital slot concentration”* you have spatial concentrations of satellite activity “*on the ground as well*” (GovPolicy2b). It is important to discuss this ‘ground geography’ because it is a key part of the industry’s organisation of production and relates directly to the *space* geography above. Additionally, it addresses the research gap created as a result of academic discussions having ignored the 'grounded nature' of the *space* industry.

4.5.1 Ground Stations

Earth or ground stations contain the support systems that send commands up to satellites and receive payload data on the ground. They are known as the "terrestrial counterpart" of a satellite and "there are tens of millions located worldwide, ranging in diameter from half a metre to thirty metres" (Fortescue *et al.*, 2003:387). The smaller ground stations include individual satellite dishes used for TV broadcasting/broadband and Very Small Aperture Terminals (VSAT) on ships and aircrafts for tracking/navigation (ESOA, 2010). The larger ground stations are those which control the satellites and are "*classically run by independent companies*", to whom satellite operators either outsource tasks to, or, alternatively, use their "*own people managing their system inside the facility*" (L.Operator1b). Ground stations commonly "operate several satellites at once" and possess the following key functions (Fortescue *et al*., 2003:495):

- Tracking of the satellites' positions;
- Telemetry downlink: provides the "ground control team with information about the functioning of the subsystems", which is used to detect faults (Fortescue *et al*, 2003:450);
- Command uplink: controls the orientation (position) and mechanisms on the satellites;
- Processing of payload data into "the formats required for the successful progress of the mission" (Fortescue *et al.*, 2003:477); and
- Communication with other Earth stations and processing centres.

The location of the Earth stations chosen for a particular satellite project depends "on the orbit and the nature of the mission" (MOD, 2010:78). First, the satellite's orbit defines the 'ground track' (the area of land from the satellite that is visible), dictating the geographical position required for the ground stations (MOD, 2010). For example, GEO satellites depend on satellites "*as close as possible to the equator*", whereas for polar orbiting satellites "*the closer the ground station is to a pole then the better*" (GovPolicy2b; S.SystemsManufacturer1b). Second, the nature of the mission determines the frequency of data downlinks and therefore how many different ground stations the satellites need to communicate with. For example, Earth observations missions require regular downlinks due to the "*large data volumes*" (Fortescue *et al.*, 2004:453). Frequent downlinks are also necessary if the satellite-enabled application promises a rapid response, for example a "*shipping report saying where the ships* are" must correlate the data "*within fifteen to thirty minutes*", so cannot afford to wait "*two to four hours"* for a data downlink (M.Applications1b). Consequently, satellite operators often require "*ground stations all over the place*", creating a global division of labour and a demand for companies to "*collaborate across national boundaries*" (M.Prime2a; S.SystemsManufacturer1a).

There are further factors which influence the location of Earth stations. For instance, the ground infrastructure needs to be in "*politically stable places*", with "*good communications"* that will allow the operators to connect with the site (GovPolicy2b). Additionally, they have to avoid "*urban canyons such as hills that can prevent visibility of the satellite*" and, if a military project, will need to be in the government's own territory "*because of the secure nature"* (GovPolicy3a). These factors have resulted in a spatial concentration of Earth stations in specific locations along ground tracks, which highlights the interaction between the *space* and ground geography of the *space* sector. The outcome of this interaction is a mutual path dependency, where the orbits lock the industry into certain Earth station locations, whilst the available ground infrastructure dictates possible orbits. This is because, if "*out of sight of the ground stations the satellite is useless*" (GovPolicy3a). This interdependency means that the launch of satellites into their intended orbit must be exact. This level of precision is reliant upon successful engineering of the launch vehicles, but also appropriately positioned launch sites. Section 4.5.2 discusses the factors which influence the locations of these sites, highlighting once again the relevance of first-nature geography.

4.5.2 Launch Sites

As with Earth stations, the locations of launch sites are influenced by a number of factors (Figure 4.3). First**,** there are the "*fundamental geographic advantages*" held by some sites, arising out of their relative position (latitude) to the height and inclination of the primary orbits (FloridaGovFacilitator4). This is important because "a satellite launcher needs to clear the atmosphere as quickly as possible", therefore "it is still relatively close to the launch site when it reaches initial orbit" (MOD, 2010: 40). Consequently, it is beneficial for the latitude of the launch site to be in line with the intended orbit, as it is "very expensive in terms of fuel to change the plane of orbit" (MOD, 2010: 40). For example, a geostationary satellite would ideally be launched from a site close to the equator. Consequently, UK telecommunications operators rely on their satellites being launched outside of the UK, with the majority "*out of Kazakhstan", "some go out of Cape Canaveral"* and the rest "*out of French Guiana"* (S.Operator3a). These distant launch sites are significant, as they incur costs and therefore impact competitiveness: "*20% of the entire launch cost is just getting it over to Kazakhstan, which adds to the cost of getting the data"* (GovPolicy3f).

Figure 4.3: Global launch sites.

Note: The sites used by UK based operators are highlighted in red. There are other sites closer to the equator not used by the UK, but these sites lack a suitable launch provider and are not in European territory, like French Guiana.

Source: Author.

Second, '*sheer physics*' influences launch site locations (L.FloridaLaunchManufacturer1). 'Sheer physics' is the natural speed of 1000mph, which can be gained from the Earth's eastwards rotation when launching from the equator (MOD, 2010). The speed gained is significantly less in more northern and southern latitudes as "*you get more of an oomph the closer you are to equator*" because it is the furthest distance from the Earth's central axis (FloridaConsultant1). This '*oomph*' is particularly valuable when launching into higher altitude orbits, as this requires larger amounts of energy to transport the satellite to its slot, thus equatorial sites are once again favoured for geostationary launches. The importance placed on this is evident from the number of launches from Cape Canaveral (see Figure 4.3), despite there being "*a lot of things that make Florida maybe not the best place",* such as the "*hurricane season*" and having to launch "*at sea level*" (FloridaGovFacilitator1b). Similarly, Baikonour, Kazakhstan was the chosen launch site for the Russian Soyuz rocket because it was closer to the equator than other areas of the old Soviet Union. For launches to lower Earth orbits, the equatorial advantages matter less, so there is greater flexibility in respect of the choice of site. The UK for example, has ambitions to establish its own '*Space* Port' by 2018, for the launch of LEO satellites and commercial spaceflights (UK Space Agency, 2014:14). However, high costs and stringent regulations pose significant barriers to the commissioning of this site, as pressures (both geopolitical and commercial) on nations to develop their own launch capabilities are often counteracted by economic and/or safety concerns. As a result:

> "…*not a whole lot of new launch sites get developed…it's usually modifications to the existing launch complexes that have to happen, to accommodate different configurations of launch vehicles*" (FloridaLaunchSiteContractor1).

This is an example of how sunk costs have locked the industry into existing launch sites, limiting the potential influence of factors that are exogenous to geographical position. Therefore, first-nature factors (physics in this case) initially influence launch platform locations, but are then self-perpetuated by a local accumulation of assets (second-nature factors).

Third, there are political considerations which influence launch site locations. For example, launchers need a "clear ground track below to guard against mishaps on route" (MOD, 2010:1-60). The definition of a 'clear ground track' varies between nation states and includes launching over water (as by US and European launch vehicles), and rural areas (Russian launch vehicles over Asia); as shown by Figure 4.3, there are also launches from sea platforms in order to remove the possibility of impacting on populated areas*:*

> "*…like if you launched from Texas you've got Cuba and it would be extremely bad if the United States has a misfire and fell on Cuba and not to mention the oil rigs that are down there too*" (FloridaGovFacilitator1a).

Additionally, the US trade regulation, International Traffic in Arms Regulation (ITAR) restricts satellites comprising of US parts to certain launch sites; "*you can't launch with the Chinese*" for instance (GovPolicy2b).

The exploration of locations of global launch sites is significant for a study on the UK *space* sector because it explains why launch provision is not a focus in the UK, since it is "*obviously in the wrong part of the globe*" (GovDefence1b). More generally, it demonstrates an interaction between the ground geography of the industry (which relates to *space* geography), and the arrangement of its production projects (Fineman and Hosking, 1990). This highlights the grounded nature of the *space* sector, whilst also contributing to the 'geography still matters' debate (Krugman, 1993; Dupuy *et al*, 2010; Sheldon, 2014). The mutual interaction between the ground geography of the industry and the arrangement of its production projects are outlined again in the next section, alongside the other interdependencies (between the industry's characteristics) that have been identified.

4.6 Interdependency and 'texture' in the *Space* Sector

Based on the chapter's analysis of the structure, *space* geography and ground geography of the satellite industry, it can be argued that there is a 'texture' to the organisation of the *space* sector. This reference signifies the "weave or web of interacting elements" and the vertical and horizontal relationships "which continually move into each other" (Fineman and Hosking, 1990:574; Cooper and Fox, 1990:575). There are two sets of strands that are interwoven to form the "weave or web" of this texture (Fineman and Hosking, 1990:574).

The first set of strands are the interdependent sub-sectors, as the analysis found that the operators and service providers are dependent on the manufacturers' satellites, whilst the manufacturers rely on purchases by the operators and service providers. This interdependency is important, as they impact on the industry's competitiveness, since developments and challenges in one sub-sector create opportunities and barriers in another. For example, the development of cubesats by *space* manufacturers have made it affordable for LEO operators to launch more satellites, increasing their footprint and resulting in a greater data set/bandwidth capacity for satellite application providers.

The second set of strands is the contextual framework which involves the external factors that impact on the interdependent production projects (Cooper and Fox, 1990). This includes the geography of frequency spectrum and orbital slots, resources which the operators and value-added service providers depend upon. Similarly, satellite operations and applications rely on an internationally dispersed network of ground stations and launch sites. The frequency spectrum, orbital slots and ground infrastructure also indirectly impact on *space* manufacturing, since the manufacturers rely on purchasing by the operators and service providers. As with all parts interacting in a "weave or web", interdependency between the *space* and ground geography was also discovered. For instance, a satellite's position depends on the geography of Earth stations and whether the ground track are visible, whilst the location of launch sites is determined by the available slot into which the satellite can be launched.

4.7 Conclusion

This chapter has outlined the structure of the *space* sector, its *space* geography and ground geography. This provides a foundation for developing an understanding of the governance, organisation and competitiveness of the UK *space* sector. There were four critical parts to this.

First, the distinctive roles and characteristics of three *space* sub-sectors (namely, *space* manufacturing, satellite operations and satellite applications) were explored. This analysis was framed by a conceptual approach, which uniquely combined the PPT and netchain models (Bryson, 2009; Lazzarini *et al.*, 2002). The outcome of which was a multi-dimensional perspective of production projects (involving both manufacturing and service activities), horizontal ties within them and vertical ties between them. The findings highlighted the diversity amongst the sub-sectors, as their production projects range from manufacturing satellite platforms to the distribution of television signals. In fact, the sub-sectors were found to be so different that, if not for their mutual reliance on one another, they could be identified as three separate industries. The interdependency between the sub-sectors is significant because it provides the economic geography literature with empirical evidence of the importance of considering both manufacturing functions and product-related services in an industry study. Additionally, it suggests potential feedback loops that need to be explored as part of understanding the industry's organisation of production. There were also found to be interactions between the satellite agents and other industries, which encourage economic geographers to avoid isolating the impact and character of their research industries from the influences of surrounding sectors. Furthermore, by combining the PPT approach with the netchain model it furthered their debates respectively, which is significant since neither have been developed beyond their initial citations (Lazzarini *et al*, 2001; Bryson, 2008). The research also developed the PPT approach by identifying that within a production project, tasks are outsourced to external subcontractors, who then also outsource further tasks. To distinguish between internal and external tasks, the outsourced tasks were identified as subordinate projects. The different tiers of subcontractors were also differentiated in Figure 4.2. This terminology is helpful for identifying when production projects involve a variety of tasks and more than one firm.

Second, orbital slots and frequency spectrum were explored, stressing the finite nature of these resources and how *space* operations depend on them. Particular emphasis was placed upon the importance of the geostationary orbit because of its geosynchronous advantages, and how being assigned a slot 'thwarts' other operators' attempts to compete, thus presenting a FMA (GAO, 2011; Finney *et al.*, 2008). These findings provided further evidence of the distinctive character of the industry and also introduced orbital slots and frequency spectrum as competitive resources.

Third, the 'grounded-nature' of the *space* sector was investigated. This involved identifying the locations of Earth stations and launch sites, which were found to be spatially influenced by the "*fundamental geographic advantages*" of particular sites (FloridaGovFacilitator4). This was significant as it proved that, contrary to the recent economic geography literature stressing the importance of second-nature factors, first-nature geography remains an important location factor (Krugman, 1993; Dupuy *et al*, 2010; Sheldon, 2014). Additionally, the ground stations and launch sites were shown to be internationally dispersed, demonstrating the global-scale of the industry, which in itself presents organisation challenges and impacts on competitiveness. The political barriers to establishing locations in certain sites were also outlined, which is important context for understanding the governance of the industry.

Finally, the interactions between the industry's structure, *space* geography and ground geography were reflected on, with comparisons made to the texture model (Fineman and

Hosking, 1990:574). This was significant, since the texture model has previously only been applied to social interactions in a micro context (Gherardi and Strati, 1990). It was argued that the first set of strands to the *space* sector's texture is the interdependency between the three sub-sectors, and the second, *space* and ground geography. However, there is another external factor which is necessary to explore before the industry's contextual framework or texture can be fully understood: governance. The next chapter explores this.

CHAPTER 5

GOVERNANCE OF THE UK *SPACE* SECTOR

5.1 Introduction

At the end of Chapter 4 it was established that governance is a critical component of the *space* sector's contextual framework as it affects the organisation and competitiveness of satellite production projects. This chapter provides a necessary insight into the governance of the UK *space* sector by investigating the impact of different forms and scales of governance on various stages of production. The primary focus of this chapter is the regulation and facilitation of the market by state policies (public governance) (Gereffi and Mayer, 2006). However, it also identifies the contribution of private actors to the governance of the UK *space* sector and the influence of private governance over industrial activity. This 'private discussion' is limited to the role of private insurers and political lobbying by firms, with a detailed analysis of the organisation of, and relationships between production tasks and projects (industrial governance) taking place in Chapter 6 (Gereffi and Mayer, 2005).

The point of entry for this discussion of governance is a blend of economic and political geography approaches, since the literature review identified that each could contribute to addressing research gaps in the other. For instance, whilst the political perspective would benefit more from considering the implications of power shifts and governance at the firm-level, the economic standpoint would profit from a less descriptive account of the impact of institutional frameworks (Prince, 2012; Smith, 2015). More specifically, a 'synergistic governance' approach frames the discussion, blending theoretical elements from micro and macro scales of analysis (Gereffi, 2014:1). This multi-level approach considers the impact of global, European and national forms (regulation and facilitation) of governance on the UK *space* sector. This approach is necessary because satellite companies are "*like Russian dolls*" (GovFacilitator2), impacted by governance across a range of nested scales (Brenner, 2001; Béclard, 2013).

The chapter follows the regulation and facilitation of five key processes which precede a satellite application's delivery to market. These processes are identified in Figure 5. The order of the processes are consistent with the examples of linked satellite production projects described by research participants. They are: (i) obtaining an orbital slot and spectrum; (ii) satellite procurement; (iii) satellite insurance; (iv) obtaining a *space* licence; and (v) delivery of a satellite-enabled application. The division of these "separate but related tasks" is a continuation of the PPT approach of the thesis (Bryson, 2009:37).

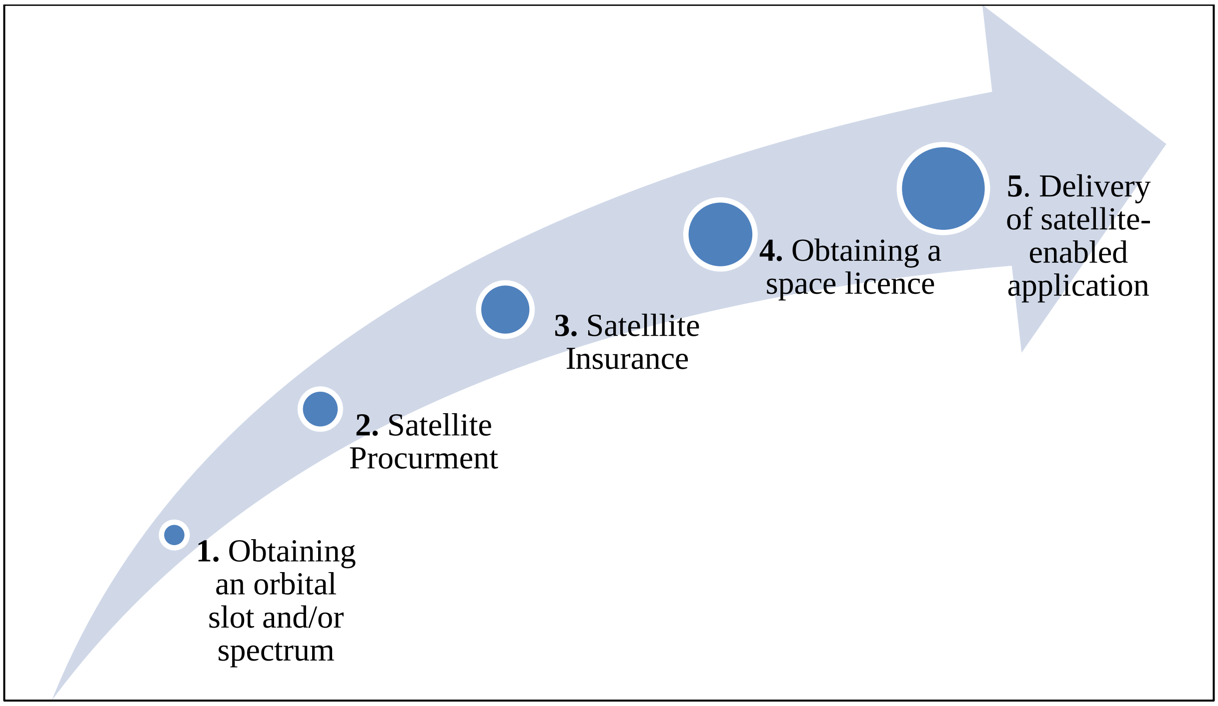

Figure 5: The processes required for delivery to market of a satellite application.

Source: Author (2016).

This chapter explores the above five processes in turn and aims to:

(i) Identify whether there are "many centres of decision making" (polycentric) involved in the governance of the UK *space* sector, which are linked across multiple scales (Ostrom *et al*., 1961:831).

(ii) Assess the balance of facilitative and regulatory forms of governance impacting on the UK *space* sector.

(iii) Outline any differences in the form and scale of governance between the varying stages of UK satellite missions (consisting of a series of linked production projects i.e. manufacturing, operating and service provision).

Whilst the five processes are discussed separately, they are interdependent. For example, you cannot obtain a UK *space* licence without satellite insurance. Therefore, the relationships between the various processes are also explored.

Prior to a discussion of obtaining an orbital slot (if a geostationary operator) and spectrum (i.e. the first of the five processes identified in Figure 5), the next section provides an overview of the governance of *space*. This identifies the ramifications of *space* being a global commons, in relation to the *space* sector's governance framework. The chapter's conceptual framework and expected contributions to the literature are also highlighted.

5.2 The Governance of *Space*, Conceptual Framework and Expected Contributions to the Literature

Space is one of "humanity's most expansive global commons" (Lahcen, 2015:54). Consequently, it is a globally pooled resource, subject to the following '*res communis*' principles: (i) cannot be owned privately or publicly; (ii) must be managed by all nations, whom are entitled to share in the benefit of its exploitation; (iii) cannot be used for military purposes; and (iv) "should be preserved for the benefit of future generations" (Lahcen, 2015:54; Shackelford, 2009:111). The governance of *space* is anchored in international treaties which embody these principles, as *space* is "governed more extensively by public international law than most other industrial sectors" (Smith and Baumann, 2011:417). These treaties are directed by the Committee on the Peaceful Uses of Outer Space (COPUOS) and are managed by the United Nations Office of Outer Space Affairs (Al-Rodhan, 2012). There are "five UN treaties regulating *space* activities" (Smith and Baumann, 2011:47). The 1967 Outer Space Treaty (OST) is the principal treaty for "regulating activities in outer *space*" and outlines the core principles that guide UN member states in relation to their actions in *space* (Al-Rodhan, 2012:194; Thompson, 1996). This global governance architecture is true of other industries which involve a commons resource. For example, the ‘high seas’ (marine areas beyond national jurisdiction) are managed by the United Nations Convention on the Law of the Sea (UNCLOS) (Rochette *et al.*, 2014; Dodds, 2010; Tanaka, 2004).

Despite the overarching global framework for the governance of *space*, provided through the OST, states retain a central role as a result of their entitlement “to a voice in determining” the use/allocation of *space* (through COPUOS) and their responsibilities with respect to the enforcement of global regulations (Cahill, 2000:242). Consequently, there is “not a single identifiable centre of authority” for *space* governance (Mazurelle *et al*., 2009:161). Instead decision making is diffused between various actors across global, European and national scales (Bulkeley and Betsill, 2005; Lobel, 2012; Zielonka, 2007; Béclard, 2013). Furthermore, “*space is an international business, so you cannot look at the UK in isolation*” when focussing on the role of the state (GovPolicy3f). Therefore, the analysis of each of the five processes adopts a polycentric approach, identifying a “multitude of policy jurisdictions” (Roe, 2009:46). Furthermore, the analysis interprets “the structure of relationships between stake-holders” (Roe, 2009:46), because in a polycentric system, governance actors do not simply “stand in hierarchical relationships to each other” (Skelcher, 2005:89). A ‘heterarchy’ is expected instead, entailing ‘many to many’ relationships between different governance actors, with “lower-level units” having relationships with “higher-level centres” (Kontopoulus, 2003; Ansell, 2000:306).

These heterarchial relationships are identified within the five processes, but also between them. For instance, an international agreement may be dependent on a subsequent national decision and vice-versa. These relationships may also involve metagovernance, where actors at one scalar level dictate "the ground rules for governance and the regulatory order" by others (Jessop, 2011:119). Interactions between different scales of governance are not only important to identify because they fit with a polycentric system, but also for furthering other political-economic debates. For example, identifying such interactions could disprove arguments concerning global scales of governance "increasingly undermining the regulatory powers of national governance" (Nadvi, 2008:331). Additionally, by considering multiple policy jurisdictions (including states other than the UK), the chapter highlights place-based differentiation, which contributes to the variegated capitalism debate (Peck and Theodore, 2007).

The analysis of the different scales of governance within each of the processes identifies the balance of facilitative and regulatory forms of governance employed with respect to the satellite industry. Facilitative governance focusses on the promotion of economic activity through enabling market creation and attracting investment. Meanwhile, regulatory governance imposes limits on the "scope of private activities" through regulation (Mayer and Pickles, 2010:2), with its rationale linked to 'market failure', since an "uncontrolled market place" fails to "produce behaviour or results in accordance with the public interest" (Cheng, 2015:382; Baldwin *et al*., 2012:9). Regulation can be defined as "a government's attempt to establish the limits to the scope of private activities" (Cheng, 2015:382). Despite the differences between these facilitative and regulatory governance however, a distinction is often not made between them in other industry studies (see Bailey and Maresh, 2009; Bennett, 2000; Eling, and Marek, 2014; Griffin, 2008; and McLaughlin and Maloney, 1999). This chapter highlights the differences and also shows how they can overlap.

The next section explores the first of the five processes which precede a satellite application's delivery to market: obtaining an orbital slot and spectrum.

5.3 Allocation of an Orbital Slot (if a geostationary operator) and Frequency Spectrum

One of the key principles of the OST is the 'registration of *space* objects' (Registration Convention 1975), since it is seen as a critical part of "preserving *space* for peaceful purposes" (Al-Rodhan, 2012:114). Therefore, all satellites intended for launch must first be registered and allocated on orbital slot (if a geostationary satellite), and coordinated radio frequency spectrum. This is an example of regulatory governance.

The allocation process is managed by the International Telecommunications Union (ITU)[5] (see Section 4.3.2). The ITU allocates orbital slot and frequency spectrum to national administrations, who then assign them to the satellite operators (London Economics, 2015). Consequently, the ITU "behaves more as a 'gateway' or liaison" rather than a central-actor or gatekeeper. This role is consistent with a polycentric system (Ansell, 2000:306).

The allocation process typically begins three to five years prior to a launch of a satellite and involves a three step process: (i) advance publication of information; (ii) coordination process; and (iii) notification of frequency assignment (see Section 4.3.2). The orbital positions and frequency spectrums are allocated under a 'posterior system' of first-come, first-served (Cahill, 2000), where "*if you file first then you have precedence*" (S.Operator2a). Consequently, there is a 'First-Mover Advantage' (FMA) with respect to slot and frequency allocation, whereby if operators apply first then they can potentially

[5] The ITU is a United Nations specialised agency for information and communication technologies. It was founded in 1865 and became a United Nations agency in 1947. It allocates global radio spectrum and satellite orbits, develops technical standards to ensure networks and technologies seamlessly interconnect, and strives to improve access to ICT for underserved communities worldwide. It is based in Geneva, Switzerland (ITU, 2016).

thwart “other firms’ attempts to compete” (Finney *et al*., 2008). This FMA has been experienced by the large satellite operators that were interviewed. By way of example:

> “*In essence we happened to be in the front and no one has used that spectrum before us and therefore we were ahead of the game*” (S.Operator2a).

The result has been the emergence of an ‘orbital market’ in which the ‘first-movers’ hold the power and may or may not sell their orbital slots and frequency spectrum to other operators (see Section 7.2.2). This is particularly relevant to the geostationary orbit, where only a fixed number of operators can position satellites in prime slots (Cahill, 2000). The establishment of the orbital market highlights the power of the commercial operators in influencing the use of *space*. This is significant as it shows the role of non-state actors in the governance of the *space* sector (Wang, 2009). It also points to the ITU’s limited power, post slot and spectrum allocation. As explained by one of the research participants:

> “*…the ITU has no teeth, it is not a police force, it’s a charter agreement which countries have signed up for… The ITU can question, ask, but they can’t tell people what to do*” (S.Operator2a).

As a consequence of the ITU’s limited powers, ‘over-filing’ or ‘paper filing’ became a significant issue for the *space* sector in the 1990’s, as such actions involved the reservation of orbital slots and frequencies by organisations, without intention for their actual use. As a result, the orbital slots exist on paper but not in reality (Allison, 2014). The motivation of the operators in taking such actions relates to the FMA (Finney *et al*., 2008), whereby operators can ‘forestall competition’ by warehousing slot and spectrum resources (Allison, 2014). There are also examples where organisations have ‘cashed in’ on their paper filings. This was true of the Tongesat case in 1988 where 16 speculative filings were reserved for the purpose of profit. The Tongesat case has become "emblematic of the gold rush" for filings (Allison, 2014:76). Paper filing is not condoned by the ITU as it is contradiction to their policy of 'equitable access' to *space*, by obstructing future operators and countries from entering the market. Nonetheless, paper filing most likely still occurs because the ITU does not financially penalise operators for "an eventual no-show" of their satellite and is thus without "*teeth*"; organisations therefore have nothing to lose by filing (ESOA, 2010). Over-filing is relevant to the organisation and competitiveness of the UK *space* sector because it obstructs "real planned satellite networks" from completing their coordination (Allison, 2014:27). This is particularly significant with the "increasing demand for use of scarce spectrum and orbit allocations" (London Economics, 2015:31).

The ITU has recently "*taken action to try and clean up paper filing*" by adding administrative due diligence criteria to the regulatory process (GovRegulator1). As part of this criteria, operators now have five years to bring a satellite into use (with a maximum two year extension) before their filing expires. This restriction was initially effective in curbing the issue of over-filing, but paper satellites (or virtual satellites as they are now registered electronically) do still exist:

> "*France… have just put in ¼ million of filings* [in low earth orbit where there are not a restricted number of orbital slots], *for me I am not aware of anything that huge, it's just enormous. That is pure spectrum holding as far as I understand*" (L.Law1).

This is due to loopholes in the system ("*if you have an application for 770 satellites and put one into use, according to the ITU that is fine*") (L.Law1), and has led to a call for a complete "overhaul of the entire regulatory framework" (Allison, 2014:29). Such an overhaul is considered necessary because speculative filings were not accounted for in the

Registration Convention (1975), as it was a time when there was only a handful of players in the market whom acted as a "*big happy family*" (S.Operator2a). As a result of this convivial market, paper filings would not occur because there was not the same "*worry that somebody was going to get ahead*" as there is now (S.Operator2a). Similarly, because the "*laws were written some time ago, before new technologies came out*", there are no regulatory concessions for cubesats (GovFacilitator1b). This is appropriate given the difference between cubesats and heavy satellites. However, as with other supranational governing bodies, the ITU is challenged by the absence of a "sovereign decision maker" and the concern with pleasing 194 member countries (Stone, 2013:25). This means that it is very difficult for all member states to agree on a consensus, thus most matters are decided upon by a "simple majority vote" (peace and security concerns require a two-thirds majority). However, a majority is often still difficult to reach if states are preoccupied by their own political agenda (Al-Rodhan, 2012:167). This makes "*changing things a monumental task*" for global *space* governance and in turn is detrimental to the competitiveness of the UK *space* sector (S.Operator2a).

The effectiveness of any regulatory changes would also rely on enforcement by member states. The significance of these national forms of governance are explored in the next sub-section.

5.3.1 The Enforcement of ITU regulations by Nation States

Nation states are responsible for the enforcement of regulations in respect of the registration of orbital slots and frequency spectrum. There are certain aspects of ITU regulations that are enforced by states in very similar ways. For example:

> "*There is a big book called the radio regulations, which regulates the use of frequencies and every country has its own version of that, although they are pretty*

> *much identical. So there will be some footnotes added - in the UK we do this and may not do this… But it is very, very similar. Space law by definition is international, so it is much the same*" (GovPolicy2b).

However, there are other global principles that are more widely interpreted and therefore differ between national contexts. For example, due diligence criteria for orbital slot and frequency allocation. The UK slot and frequency allocation is managed by Ofcom[6], a communications regulator that is "legally and organisationally" separate from government departments (Coen and Thatcher, 2008:55). Ofcom is, therefore, identified as an Independent Regulatory Authority (IRA), with equivalent IRAs managing slot and frequency allocation for other countries. In other heavily regulated industries such as aviation and rail, there are also European regulators who oversee national regulations (Groenleer *et al.,* 2010). This, however, is not the case in the satellite industry, since the "government and corporate uses of *space*" are controlled by a national regulator (Johnson, 2007:168). This demonstrates the relative importance of governance at a national level to the *space* sector, in comparison to other sectors. Furthermore, it counters the assertion in the literature that "national policy instruments" are being "eroded by supranational powers" (Mclaughlin and Maloney, 1999:1).

In common with the maritime and aviation industry, nation states "do not always comply with their legal obligations" (Groenleer *et al.*, 2010:1212). The level of compliance

[6] Ofcom is an independent regulator and competition authority for the UK communications industries. Ofcom was established in 2002 by the Office of Communications Act to represent the interests of citizens and consumers by promoting competition and protecting the public from harmful or offensive material. One of their main areas of activity is licensing and protecting the radio spectrum from abuse (Ofcom, 2016).

depends on the IRA, which vary considerably in “age, powers, autonomy, finances and staffing” (Coen and Thatcher, 2008:55). By way of example:

> “*It goes from squeaky clean to absolutely corrupt. There are countries where you can go off and pay the bribes and get hold of an orbital slot, it’s not recommended, but it is done*” (GovPolicy2b).

For example, in 2011 Anatel (the Brazilian equivalent of Ofcom) opened a “bidding process for four orbital satellite positions”, with a minimum price set at US $2.4 million, despite the OST principle of non-appropriation (Satellitemarkets, 2011).

In contrast, other regulators are far more diligent and have developed additional legislation alongside the ITU principles. Ofcom for example, would prohibit a 770 satellite system being ‘brought into use’ by a single satellite (as ITU regulation allows), as they stipulate that “*minimum satellites must fly to provide the minimum quality*” (L.Law1). These national differences are important, because, in the event an operator would prefer to comply with a set of regulations of a particular country, then that operator would need to be legally registered in that country. Therefore, allocation regulations can influence the location of firms in the *space* sector. “*Any country can register for any* [orbital slot and spectrum] *position*”, so the operators are free to choose where to register (L.DTHApplications2). To Potts (2016:523), all large firms across different industries “exploit regulatory variation across jurisdictions by exporting activity to strategic locations around the globe”. For example, in the motor vehicle industry there is evidence of companies locating their manufacturing plants in jurisdictions with “less stringent environment regulations” (List and Mchone, 2000:177). Similarly, advance business services (accounting and financial services) locate in offshore jurisdictions to “escape the control of governmental or intergovernmental organisations” (Wójcik, 2013:331). For instance, jurisdictions such as Bermuda, Luxembourg, Ireland and Austria are known as 'tax havens' or offshore financial centres and are used by advanced business services, as well as large corporations such as Starbucks, Amazon and Google, to avoid tax (Coe *et al*., 2014; Haberly and Wójcik, 2014). There is also evidence of US corporations merging with smaller companies in the UK, Ireland and the Netherlands "in order to move their registered offices to lower tax jurisdictions" (Clark *et al*., 2015:247).

The influence of regulations over location choice is identified as "jurisdiction selection" and results in jurisdiction shopping with office locations (Clark and Monk; 2014:531). For example, "*people locate in Papua New Guinea to make a filing because it is easier there*" (L.Law1). This is possible because the headquarters of satellite operators are not tied to any particular infrastructure or location. The location of the operators' headquarters (where they file for slots and spectrum) are distinct from their office locations, which are within close proximity to the operators' target markets (Chapter 4, Section 4.2.3). Consequently, the UK Government (through the UK Space Agency) works with Ofcom to try and attract satellite operators to establish their headquarters in the UK. Ofcom's regulatory procedures however, have been criticised as being too *"strict"* and *vigorous*", compared to other IRAs which are more lenient and "*flood the ITU with filings"* (M.Operator2; S.Operator2a). Therefore, Ofcom's diligence can be considered as a "*market blocker*" to satellite operators and detracts foreign direct investment (FDI) (GovPOlicy3c). The difference between Ofcom and other IRAs is due to a "significant leeway" in the power of and approach taken by national regulators (Finger and Varone, 2006:6), where "*not everyone plays by the same rules*" (M.Operator2). It is an example of place-based differentiation.

Despite the stringency of Ofcom, the UK is attractive to satellite operators for a number of reasons. For example, it has a favourable corporation tax and, unlike the US, "*doesn't charge for spectrum*" (GovPolicy3e). The UK is also considered a "*supportive muscular state that would represent company interests at an international level*" (L.Law1). These factors are part of the UK's "*historic reputation for doing things right*" and how "*having a highly respectable, highly competent regulator…is very important*", especially if you are "*doing something relatively new*" (Gov.Regulator1; S.Operator2c). Therefore, although the UK is comparatively strict from a regulatory perspective, many companies have chosen to locate in the UK because Ofcom is a strong and reputable regulator to associate with: "*a bit of a flagship around the world… that often helps in other territories*" (S.Operator1b). Consequently, there are examples of companies who have "*opened up UK offices so that they could file satellites through the UK administration*" (GovRegulator1). This evidence of jurisdiction selection is significant as economic theorists (Bolton and Dewatripont, 2005) have often taken for granted the influence of "well-functioning legal systems" on firm location choices (Clark and Monk, 2014:11). The varying approaches of different IRAs to slot and spectrum allocation also highlights the significance of the national scale in the industry's governance framework, which contradicts Nadvi's (2008:331) argument of how the global scale increasingly undermines "the regulatory powers of national governance".

5.3.2 Section Overview

This section has focussed on the governance of the orbital slot and spectrum allocation process, within UK satellite missions. The analysis found the governance of this process to be 'multi-level', occurring at a global and national level (Venet, 2012:60). It is also polycentric, as with both the ITU and IRA's involved, there is more than one centre of decision making and an absence of a hierarchy between them. Instead, the ITU behaves more as a gateway rather than a gatekeeper (Ansell, 2000), with the state responsible for enforcing and interpreting global regulations. This counters the argument in the literature of "national policy instruments" being "eroded by supranational powers" (Mclaughlin and Maloney, 1999:1). It also leads to jurisdiction selection, as states interpret ITU regulations differently, which can influence the location choices of operators (Mclaughlin and Maloney, 1999). This section also found that commercial operators govern the use of *space* through orbital slot markets. This is significant, as it shows the role of non-state actors in the governance of the *space* sector and highlights another centre of decision making in the polycentric process (Wang, 2009). The form of governance involved in this process is all regulatory, highlighting an imbalance with regulatory forms of governance in this part of a satellite mission.

5.4 The Procurement Process of Satellites

Once an orbital slot and frequency spectrum has been negotiated, the next phase of a satellite mission (consisting of a series of linked production projects) is the procurement of the satellite. The procurement process of UK satellites is primarily impacted by facilitative and regulatory forms of governance on a national, European and global scale. Satellites can be grouped into three types: (i) civil; (ii) military; and (iii) commercial, each of which adopt different approaches to procurement (Johnson, 2007). This section focusses on institutional (civil) satellites, since their procurement process is the most varied and complex. Civil satellite missions are also particularly relevant since "nearly half" of orders for satellites are placed by "public customers, such as the European Space Agency and national *space* agencies" (Smith and Baumann, 2011:417). Nevertheless, general lessons for all satellite types (including military and commercial) are drawn in the section overview. The procurement process is a critical stage in the organisation of production. Therefore, this section provides a response to Jones' (2014:608) call for theories on organisation and governance to be better integrated. The first sub-section outlines the facilitative and regulatory governance of UK satellite procurement, by the European Commission and European Space Agency (ESA)[7].

5.4.1 European level Governance of UK Satellite Procurement

As part of the UK's membership in the European Union[8] and the European Space Agency (not all EU members are ESA members), UK satellite manufacturers have the option to be involved in the European *Space* Programme's civilian satellite projects (GovPolicy3c). There are "two captains of the European spaceship" creating these projects and imposing a governance framework on the procurement process: (i) the European Commission; and (ii) the European Space Agency (ESA) (Mazurelle *et al*., 2009:156). Although independent, these "two organisations share a joint 'European Strategy for Space' and have together developed the European Space Policy" (ESA, 2016). ESA has historically been the primary European *space* actor, focussed on developing Europe's *space* capability and delivering benefits to both European and global citizens (ESA, 2016). In recent years however, the Commission has become more active and undertaken an "increasing number of *space* projects" (Hansen and Wouters, 2012:94). ESA and the European Commission take two

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[7] ESA is a European organisation aimed at coordinating the financial and intellectual resources of its members, so it can undertake programmes and activities far beyond the scope of any single European country. It was established in 1975 and headquartered in Paris, France. It is funded by financial contribution from the Agency's 22 Member states, calculated in accordance with their gross national product, and in 2012 had a budget of €4020 million. The European Council is ESA's governing body, who provide the basic policy guidelines within which ESA develops the European space programme.

[8] Current members of the European Union (March 2016): Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the UK.

different approaches to civilian satellite projects: (i) the procurement of complete satellites where they act as an institutional customer (90% of ESA budget); and (ii) the financing of satellite technology via public private partnerships (PPP) (10% of ESA budget) (GovPolicy2c). Both are examples of facilitative governance, as they encourage market creation and attract investment (Mayer and Pickles, 2010; Aschhoff and Sofka, 2009).

In broad terms, the projects of the two organisations are distinguished by the European Commission focussing on a set of key applications (satellite navigation and Earth observation), and ESA focussing on technological developments, access to *space* and scientific responsibilities (Mazurelle *et al.*, 2009). For example, a recent commission project is the Galileo programme, a 30-satellite constellation[9] aimed at providing Europe's own Satellite Navigation System. Meanwhile, a recent focus of ESA has been the development of an "*all-electric satellite, with no chemical propulsion*" (GovPolicy2b). A similarity between these projects is that they both target the manufacturing portion of the *space* sector. This is representative of the share of investment between the upstream and downstream sectors in European projects, since:

> "…*the money that we put into a new satellite project is measured in terms of tens of millions of euros. Whereas the money that will go into a downstream project is tens of thousands*" (GovPolicy2b).

The operators and application providers indirectly benefit from any upstream projects, as advancement in satellite technology is "*relevant to their evolution*" (L.Operator1b). Nevertheless, the focus on the downstream sector is evidence of the varying levels of facilitative governance, for different economic agents across the UK *space* sector.

[9] A satellite constellation is "a group of similar satellites that are synchronised to orbit the earth in some optimal way" (Kidder and Vonder Haar, 2006).

One of the primary motivations for UK satellite manufacturers to be involved in ESA and European Commission-led projects, is that they facilitate collaboration between different countries, fostering the sharing of expertise (GovPolicy2c). This is valuable, as due to the high costs and complexities of *space* missions, "a sizeable and increasing number… involve some degree of cooperation" (Brown, 2013:222) and can sometimes only be achieved "through a multinational effort" (Marta, 2013:21). Another motivation is that the projects often incorporate "*brand new technology, that's very high risk and has never been done before*" thereby presenting an invaluable opportunity for manufacturers locked into a conservative and risk adverse industry (L.Prime1c; Billing, 2013). This is evidence of how innovation decisions and market potential (and therefore competitiveness) can be shaped by public governance. ESA projects also provide opportunities for subsequent commercial contracts, as the primes' often procure the same suppliers to maintain consistency with the prototype design:

> *"The ESA project is only the prototype. ESA then hands these projects on to some other parent body and then there may be another order of half a dozen"* (GovPolicy1).

Being involved in ESA projects also has a positive impact on a company's subsequent commercial business by being good for its reputation, as evidence of work with ESA can give "*commercial people anywhere else confidence that it is a company that knows what it is doing*" (S.SystemsManufacturer1b). This highlights the lasting impact of ESA governance on the organisation and competitiveness of the UK *space* sector.

Meanwhile, ESA and the European Commission are motivated to develop these projects because of the 'public good' arising from the satellite's application and the security and sovereignty concerns coupled with *space.* Additionally, procuring and financing satellite projects is a form of "defensive protectionism" (Morgan and Sayer, 1988:30), made in an effort to "*give European manufacturers a head start against other global manufacturers, who are supported by their governments*" (GovPolicy2b).

The procurement process for satellites, funded by PPPs, is typically led by the commercial manufacturers, although ESA and the European Commission can "*help companies to find partners*" and provide "*technical expertise*" (GovPolicy2a). For projects where ESA and the European Commission are institutional customers, procurement is governed by two different sets of principles: (i) 'juste retour' (ESA projects); and (ii) competition (European Commission projects). *Juste retour* (geo-return) or 'fair-return' is a principle applied to all ESA projects, where a country's share in the value of contracts for a project is in proportion to the share of the budget it contributed towards the project (ESA, 2016; Schmidt-Tedd, 2011). In contrast, European Commission projects comply with the principle of competition, in which procurement is not determined by budgetary criteria, but a competitive tendering process, with only defence-related restrictions (European Commission, 2016).

Since the number of ESA satellite projects is greater than those of the European Commission, the majority of European-procured satellites are subject to the *juste retour* principle (Schmidt -Tedd, 2011). This places significant restrictions on the organisation of production; prime manufacturers are not free to choose their suppliers as they would in commercial projects:

> "*…you go to ESA and they will say 'right 12% of your programme needs to come from the UK, 30% needs to come from France, 20% needs to come from Italy, 10% needs to come from emerging countries like Poland, Romania, Czech Republic' so*

> *you win the programme, but you win it on the basis that you can't use your own company to do the work, you have to get other companies to come in from other nations*" (M.Prime1a).

Juste retour is particularly restrictive when certain countries are guaranteed procurement contracts (based on their budget contribution), but "*come from quite a low place in terms of space capability*" (S.SystemsManufacturer1a). As a result, it is *"not necessarily the best country or company that gets the job*", affecting the competitiveness of the end-products (L.Prime1c). Consequently, some firms choose not to bid on ESA projects, "*because they are not strategic and they will cost money*" (M.Prime2a). *Juste retour* also impacts negatively upon UK component manufacturers as, if the prime contractor is based in the UK, "*the battery manufacturers, the solar array manufacturers and so on have to come from other European states, in order to balance the geographical return*" (GovPolicy3d). Furthermore, an over-reliance on ESA projects has the potential to create an "*artificial funding mechanism*" that is vulnerable to the impacts of policy change (S.SystemsManufacturer1a). This evidence of the restrictions placed on the procurement process by the *juste retour* principle contributes to filling a gap in the literature as it is an example of how a facilitative form of governance (i.e. procurement opportunities) can also be a regulatory form of governance, which in turn highlights the difficulty in separating the two. Furthermore, it demonstrates how governance measures are not always in the interest of the whole industry, since their impact can vary between different agents involved in different stages of production.

Despite the challenges of *juste retour,* by bringing collaboration and technological opportunities, ESA projects remain very valuable to UK satellite manufacturers with "*a lot of companies… simply chasing ESA projects*" (GovPolicy3d). Consequently, as with orbital slot and spectrum regulation over operators' locations, ESA projects influence the location decisions of manufacturers:

> "*…one of the big drivers of us being here was the UK Government, as of 2012, it has put a lot of money into ESA"* (M.Prime1a).

According to one research participant, ESA procurement opportunities "*in the last couple of years"* have encouraged as many as "*14-15 companies to have set up in the UK*" because of the potential benefits outlined above (GovPolicy3b). As submitted by Lane and Probert (2004:249), this is evidence of firms coordinating their production in ways "*for which there exists institutional support*", and is significant, as it highlights the impact of governance on the organisation of production. However, there is the "*risk of cannibalising their domestic industry by encouraging these new entrants*", so the government is cautious to ensure that they are not 'brass plate' organisations, but instead will employ and contribute towards the economy (GovFacilitator1c).

5.4.2 National Level Governance of UK Satellite Procurement

The benefits of ESA projects, which include attracting overseas investment, are used by UK government officials to justify why 80% of the UK *space* budget goes to ESA. This high percentage means that "*ESA is the driving force in a lot of what happens in the UK*"; whereas other countries, such as France, allocate a higher budget for national programmes (50%) (GovPolicy3d). This suggests that ESA is a dominant governance scale in the UK satellite procurement process and perhaps even hierarchical over national scales. However, "member states remain in control to a very large extent", as it is up to them how much they contribute to the ESA budget (Mazurelle *et al*, 2009:62). For instance, the UK increased its contribution by 30% in 2012. The UK Government also choose which optional ESA programmes they "*subscribe to and how much they put into them*", determining which projects are available for UK based manufacturers to bid on (Govfacilitator1b). For example, the UK is by far the biggest contributor to ESA's Integrated Applications Promotion line (IAP), contributing "*over 50% of the entire European funding*" and creating IAP opportunities for UK companies (Govfacilitator1b). Furthermore, member states have the power to decide on ESA's direction, through "sitting on the Council" and influencing "the EU's position and priorities" (Marta, 2013:23). Policies are also "generally guided by the advice and expertise of the most powerful supplier firms" (Morgan and Sayer, 1988:31). This is true of the UK *space* sector and ESA's programmes as there are "*a few players who are very powerful, companies… and have a lot of sway*" (GovPolicy3c). The smaller satellite companies however, "*don't really have the resources to exert power in a strong way*" and are thus unable to have the same influence (GovPolicy3c). Nevertheless, there is evidence of private actors influencing the governance of the procurement process in the UK *space* sector. This influence counters the hypothesis that ESA is a dominant and hierarchical governance scale.

The UK Government also imposes its own procurement process through trade regulations, which are as influential as those at the European level. They are important because, unlike ESA's procurement rules, they apply to commercial and military projects. For example, UK export regulations impose a "*go, no go*" rule on whether manufacturers can proceed with certain customers and suppliers (L.Prime2c). Participation in "international *space* projects" also exposes manufacturers to foreign national laws and trade regulations (Smith, 2011:54). For example, the International Traffic in Arms Regulations (ITAR) is a US export control which regulates the "export and temporary import of 'defence' articles and services" (ITAR, 2016). If a UK satellite has an ITAR-listed component, it may not be able to sell that component to certain countries or at all. Therefore, ITAR influences whether firms want, or can, access US components. Moreover, if firms do access US components, ITAR dictates whether they are "able to engage with global markets" or whether they will be limited to a select group of markets (Neilson *et al*., 2014:3). It is beyond the scope of this thesis to discuss the implications of ITAR, but the brief discussion above highlights the significance of national governance scales to the UK *space* sector and how this governance is not limited to the UK institutions.

Although the UK Government does not procure national programmes like other European countries, it does invest in "*emerging technologies*", which are then made available in the market and can influence the procurement process (GovFacilitator1c). This financial support is part of the 'renaissance' of the UK Government's interest in UK *space* since 2012. It encourages market creation since "R&D and innovation are essential to progress" in the *space* sector, but lengthy and expensive development times mean firms "are not inclined to take commercial risks" when returns on investment are not guaranteed (London Economics, 2015:32). Government grants therefore:

> "*…do give you the opportunity though of doing more technology development, when you can't really do R&D on commercial missions*" (L.Prime2a).

As argued in the literature, government grants are justified by expected rates of return from "future tax payments" (Hanson and Rohlin, 2011:427). These payments come from taxing the satellite services and also taxing employees. Other motivations for supporting satellite procurement include "enhancing national prestige, demonstrating technological leadership or furthering international competitiveness" (Rose, 1986:98). As aforementioned, there is also 'public good' from satellite-enabled applications and a "*reliance*" on satellite communications (satcoms) by military operations (GovDefence1b). These motivations for involvement in the *space* sector mean that the satellite industry is heavily subsidised by governments worldwide and "the *space* market does not follow the classical rules of competition" (European Commission, 2013). The result is a "state sponsored culture" (David *et al.*, 2000:497), with evidence of the grants substituting private R&D:

> "*So if* [L.Prime1] *or* [L.Prime2] *want to develop a new payload for the generation of satellites, their first thought is, I'm going to get a grant for that and it will be £50 million… Ford don't do that, Apple certainly don't do that, so why does the* space *industry need to do that?*" (L.Prime1b).

Whilst being further evidence of facilitative governance on a national level, this 'state sponsored culture' could be detrimental to the long-term competitiveness of the UK *space* sector (Mayer and Pickles, 2010:2).

5.4.3 Section Overview

Overall, the governance of the procurement of UK institutional satellite projects are framed by "legal norms that emanate from…European and national legal frameworks" and influenced by private actors (Venet, 2012:59). The result is a multi-level governance structure, with relationships and interdependence between the European, national and subnational levels. The balance of power between these governance actors is evenly distributed, suggesting a polycentric governance system. For example, national governments impose their own procurement rules through trade regulations, which are as influential as those at the European level because, unlike ESA's procurement rules, they apply to commercial and military projects.

Facilitative governance was more apparent than regulatory governance, with European procurement and national R&D extending the "technologically possible" (Perez, 2009:2). However, this was found to largely apply to the upstream sector, with varying levels of facilitative governance impacting different economic agents. Furthermore, an analysis of the *juste retour* principle highlighted how a facilitative form of governance (i.e. procurement opportunities) can also be a regulatory form of governance and how it is difficult to isolate the two.

The orbital slot/frequency spectrum allocation and procurement process have both highlighted the role that state actors play (on a national and supranational level) in the governance of the UK *space* sector. However, public governance is not the only mechanism of control over UK satellite missions, as non-state actors are also involved in the regulatory process. For example, private insurers make up the "much wider regulatory landscape" (Grabosky, 2013:114). These private insurers are the primary focus of the next section, where the satellite insurance process is explored as the next phase in a satellite mission.

5.5 Satellite Insurance Process

Up until the 1960's, most satellites were launched with military aims. Thus, historically satellites were not insured, since they had "no direct revenues associated with them" and any risks were "retained by governments and the Space Agencies that financed" them (Manikowski and Weiss, 2013:151). This is no longer the case for the present commercial *space* market, in which satellite operators are responsible for obtaining their own private insurance to protect their revenues. This section focusses on the satellite insurance process, which is managed by private insurance firms who "set standards" and "enforce compliance" (Scott, 2002:65). It contributes to the literature, since regulation by "non-state organisations are an important but neglected aspect of contemporary governance arrangements" (Scott, 2002:56).

Satellite insurance is a "relatively small but international community" (Manikowski and Weiss, 2013:151), with only "*about 35 satellite insurers worldwide*" (L.Insurer1). These are concentrated within Europe (London, Paris and Munich) and the US (New York and Washington DC), with the UK accounting for the greatest number, with "*30 to 35% of the international market*" (L.Insurer1). As with "*any insurance*", they allow:

> "…*the entrepreneur or operator to take out risk, safe in the knowledge that if something goes wrong then they will get their money back.*" (L.Insurer1).

However, these risks are greater than in other industries, such as aviation, because "*whereas you can replace the wing of an aeroplane, you can't go up into orbit and repair a damaged satellite"* (L.Insurer2). Therefore, insurers arguably play a more critical role in the satellite industry than in other industries.

Montpert (2011:238) considers satellite insurance to be "designed for protecting against the financial consequences of events occurring between lift-off of the satellite and its end life". Satellites tend to be insured against known events, including environmental (i.e. *space* debris, solar flares etc.) and military threats (i.e. deliberate actions by a non-insured party). However, damage to a satellite can be caused by "*anything*" (L.Insurer2). For instance:

> "…*we had a claim last year because of a piece of Velcro that got stuck in a communications valve; they used Velcro when they put the thermal blanket on the satellite and a stray piece got stuck in the communications valve. And that was a claim of $214 million*" (L.Insurer1).

There are two types of satellite insurance: (i) damage insurance, which "*protects the commercial company*"; and (ii) liability insurance, which "*protects national interests*" (L.Insurer1). Both of these types of insurance are discussed below.

5.5.1 Damage Insurance

Damage insurance or 'asset insurance' is "designed to protect operators against the physical loss or the reduction in performance of a satellite" (Manikowski and Weiss, 2013:177). It can be purchased by operators in different forms, which cover satellites for different periods of time, for instance, "*launch phase*", "*post-separation"*, "*first 12 months of in-orbit exposure"*, "*ten years*", and *"design life of the satellite"* (L.Insurer2). The most commonly purchased form of damage insurance is 'launch phase' because it covers "*the most difficult and the most demanding*" part of a satellite mission, where "*for 90 seconds you have a chance of your entire $400 million going up in smoke*" (L.Operator1b). A typical launch phase policy will cover the first year, including:

> "*… its launch, deployment of the solar arrays, deployment of the antenna, the orbit raising that is required, getting the satellite into its final position, a months' worth of in-orbiting testing, and maybe the first 11 weeks or so of the in-orbit operations*" (L.Insurer1).

Such policies cover events such as faulty designs, ground operator mistakes and inadequate testing (Montpert, 2011). Claims can be for the full loss or can be "*partial*" or proportional (i.e. where one out of ten transponders is lost, a "*10% claim*" is made) (L.Insurer1).

The premium for a launch phase insurance policy depends on the value of the launch vehicle together with the mode of launch. For a "*$100 million satellite*", the premium would be 2% to 2.5% of the value (US $2 to $2.5 million) if launched on the Ariane 5 (European), 3.5% to 4% on the Falcon 9 (US), and 10% on the Proton (Russian) (M.Operator1b). Presently, premiums are comparatively higher for launching on the Proton due to "*quality control issues*" causing a higher launch failure rate: "*in the last eight years there have been 40 claims in the market and 75-80% of those are due to the launch* *vehicle*" (L.Insurer2; L.Insurer1). Premiums are also influenced by the mission to be performed by the satellite, financial stability of the operators and the heritage of the satellite design (i.e. flight history of the components and the experience of the manufacturer). Heritage is explored in Chapter 7 (Section 7.3) and influences both the operators' choice of supplier and manufacturers' procurement of components. For example, manufacturers are expected to be risk averse during the procurement process for commercial projects, in order to minimise the cost of insurance for their operator customer:

> "*…so everyone is completely risk adverse and even if you said 'this 3cm diameter bolt is new' then the insurance would probably go up by millions and genuinely millions*" (M.Prime1a).

This highlights a relationship between the governance by insurers and the organisation of production.

Operators can also buy loss of revenue insurance, but "*typically the revenue is much more than the asset, so people tend not to buy it because you are talking $1 billion of revenue*", which would result in a significantly higher premium (L.Insurer1). Operators may also decide not to buy any damage insurance at all, but instead manufacture a reserve satellite:

> "*So what we have done is commission a fourth satellite, it's generally what we do and then we stick it in a warehouse and either leave it on the ground as a back-up… If the capacity or the fill rate is high then we will launch it, but it may sit there on the ground, it's a lot of money, but it's perhaps a better insurance policy*" (L.Operator1c).

This is an expensive option but has the advantage that it can quickly be launched into orbit if needed, which means less revenue is lost through service downtime. Consequently, out of the 1,167 active satellites in orbit (in 2014) "*about half of them are commercial and* *about half of them are insured*" (Kunstadter, 2014; L.Insurer1). This is significant, as it demonstrates that with damage insurance the decision, and therefore the power, ultimately lies with the operator.

5.5.2 Liability Insurance

In contrast, it is compulsory for UK operators to purchase a minimum of €60 million of liability insurance coverage (UK Space Agency, 2016). Therefore, the governance by private insurers over the UK *space* sector is dependent on the type of insurance. Unlike damage insurance, liability insurance protects the satellite operator and the launching state "against the financial consequences of damage caused to a third party" (Montpert, 2001:283). This damage could be to the Earth's surface or to objects in the air (Al-Rodhan, 2012:198): "*so if a launch vehicle blows up and crashes into property on the ground, you have to reimburse that state fully*" (L.Insurer1).

Liability insurance is based on the Convention on International Liability for Damage Caused by Space Objects (1972) and Article 7 of the OST, which stipulate that "launching states are responsible to third parties for any damage induced by one of their satellites" (Montpert, 2001:284). This impacts the UK as, although it is not a territory where *space* objects are launched, the term 'launching state' also includes any state which "procures the launching of a *space* object" (Al-Rodhan, 2012:198). Consequently, along with the majority of "countries involved in *space* activities", the UK passed a law obliging operators to purchase "third party liability insurance of a minimum specified level" (Montpert, 2001:284). This is evidence of metagovernance, where governance at the supranational level has set "the ground rules for governance and the regulatory order" on a national level (Jessop, 2011).

In this instance, the relationship between the supranational and national actors is not hierarchical, since the minimum specified level of liability insurance is set by the nation state (Cooper and Fox, 1990:581; Kontopoulus, 2003; Jessop, 2011). Therefore, the level varies between jurisdictions and is another factor which can influence operators' location decisions (particularly small and medium sized enterprises (SMEs) who cannot afford high costs). For example, prior to 2013, the UK did not have a minimum specified insurance coverage level, but instead "*unlimited liability*", where operators "*were responsible for reimbursing the whole cost value*" (L.Insurer1). This exposed operators to "*unknown risks*" and made the UK an undesirable environment (L.Insurer2). Therefore, the UK government recently introduced a minimum specified level of £60 million, which is more in line with other European countries, such as France (€60,980,000) (Montpert, 2001:284). Today, liability insurance remains compulsory for all UK operators, which "places the insurer in the role of a government enforcer" (Bennet, 2000:887). On the one hand, this shows a partnership between private and public actors involved in the governance of the *space* sector (Griffin, 2008:471). On the other hand, it highlights how private insurers have not constrained governmental activities, since the state continues to decide minimum requirements (Scott, 2002; Bennet, 2000).

5.5.3 Section Overview

This section has outlined the critical role that private insurers play in the governance of the UK *space* sector. This is significant, as it furthers the political-economic argument that governance is neither public nor private (Bartley 2007; Black, 2001; Grabosky, 2013), as it is too "complex and fragmented" to be categorised solely into one realm (Bennet, 2000:876). Furthermore, this section highlighted the interactions between supranational, national and private actors. Such interactions involve metagovernance between supranational conventions (i.e. OST and liability conventions) and national laws (i.e. minimum liability level). Additionally, a partnership between the UK government and private insurers (as enforcers) has been observed, emphasising the continuing role of the state. This analysis also highlighted how, with damage insurance the decision, and therefore the power, ultimately lies with the operator. This reflects the influence that private firms have over the industry. In summary, there is a network of both public and private governing actors found on a range of spatial levels, which is further evidence of a polycentric governance system impacting the UK *space* sector. Moreover, the dominant form of governance is regulatory, with no evidence of facilitative governance influencing this process.

Once a satellite has a registered orbital slot/ frequency spectrum, undergoes procurement and has the minimum required level of insurance, the next phase of any satellite mission is obtaining a *space* licence. This process is explained in Section 5.6.

5.6 Obtaining a *Space* Licence

A *space* licence is required before a satellite can be launched and an operator can enter the market. The licensing process is "*completely separate*" from the registration of an orbital slot/frequency spectrum, as it comes much later in a satellite production project (typically six months to a year in advance of launch, as opposed to seven years in advance for slot/spectrum registration). Licences are awarded by the UK Space Agency, as opposed to Ofcom. In 2014, "*21 UK space licences were issued*", which was a "*60% increase on the year before*" (GovPolicy3e).

As with the registration and insurance process, *space* licensing is an example of regulatory governance where regulation constrains the industrial activity of firms (Mayer and Pickles, 2012; Dicken, 1992). As with the registration of orbital slots and frequency spectrum, the "*corner stone of UK law*" on *space* licences "*comes from the UN treaties*" (GovPolicy3b). More specifically, as part of the UK government's compliance with the OST it must ensure that:

> "…*space* activities carried out by UK individuals or organisations: (i) do not jeopardise public health or the safety of persons or property; and (ii) are consistent with the international obligations of the UK" (Gov.UK, 2015).

The UK introduced the *space* licensing process in response to the OST, by preventing excessive risk, through managing what can and cannot be launched by UK satellite operators. This prevention of risk affects the "diffusion of new technologies" and therefore influences the organisation of production (Gruber and Verboven, 2001:1190). It is an example of multilevel governance, where "power rests in the hands of central authorities", but where central decisions are influenced by metagovernance from supranational treaties (Zielonka, 2007:191).

5.6.1 National Variation of *Space* Licensing Regimes

Despite the OST being an international agreement, the *space* licensing process is based on national interpretation and therefore varies between jurisdictions (Mazurelle, 2009). For example, different licensing regimes place more or less importance on certain criteria. In the UK, there are three key considerations:

- Financial: this typically involves a credit check, to assess whether the operator has "*the means to carry the activities out and can afford the insurance that we* [UK Government] *expect to be in place until deorbit*" (GovPolicy3e). Credit checks are valuable as they not only highlight the operator's financial stability, but also their flight history, where "*if you've got a company that's already operating then you* *are obviously going to consider their satellite more likely to go ahead*" (GovRegulator1).

- Insurance: "*an independent assessor, who will look at the insurance and make sure the UK government is named on it and that it meets our requirement for 60 million Euros for launch and in-orbit phases of the mission*" (GovPolicy3e).
- Technical: operators will need to answer a set of questions about their technology and the satellite's mission; their equipment and facilities may also be subject to "inspection and testing" (Gov.UK, 2015). These checks assess the readiness level of the satellite technology, any national security concerns, and the risk based on whether the operator has "*a proper manufacturer's contract*" (GovRegulator1).

As part of the licensing process, operators are also required to provide a "*deorbit plan*", which is checked to ensure "*they have enough fuel to execute it and that it's safe and good*" (GovPolicy3e). This is because as part of their 'International Obligations', the UK Government is obligated to manage the disposal of licenced *space* objects "at the end of the licenced activity" (Gov.UK, 2015). The end of licenced activity will be the end of the satellites life span, which is "generally ten to fifteen years" (Copiz, 2001:211). The deorbit plans follow Space Agency guidelines, which are based on Global legislation. For instance, a "*geostationary satellite needs to be taken up 300km to a graveyard orbit above*" (GovPolicy3e). This requires the operators to "*save sufficient fuel for the final burn which takes them out of their geosynchronous orbit to a graveyard slot*" (L.Operator1a). Deorbit plans are so important because *space* debris (a defunct and decommissioned satellite) poses a threat to future access to *space*, as *one small chunk of debris could take out a billion dollar satellite*" (S.SystemsManufacturer1a) and "cause catastrophic damage" (Trapp, 2013:1712). Such threat counters the sustainability principle of the OST. Therefore, there is pressure from other national institutions and supranational bodies on the UK government to manage the disposal of its licenced *space* objects. This highlights the external influences on State-centred governance and is evidence of there being a multi-level governance system in place with ‘many to many relationships’ (Cooper and Fox, 1990; Kontopoulus, 2003).

However, the national variations are not limited to different licensing criteria, as not all countries have a licensing procedure. In Europe, for instance, “*there are only six member states in the EU that have licensing regimes”* (L.Law1), namely: Sweden, UK, Belgium, The Netherlands, France and Austria (Space Institute, 2013). The other member states (e.g. Spain) “must also authorise and supervise” their *space* activity, but do not have a fixed licensing system in place (Space Institute, 2013). Without such a system in place, those countries may appear more lenient and thus may be selected by operators over jurisdictions such as the UK. However, without getting “*a country of clout to give them a licence and accept liability for them*”, operators can “*have a real problem in the international market*” (L.Law1). Therefore, the UK’s “*stable regulatory environment*” is more attractive to many operators than countries without a licensing regime (GovPolicy3f). This national variation in the *space* licensing process, as well as with spectrum/slot registration, is evidence of the geographical differences identified in the Varieties of Capitalism literature (Peck and Theodore, 2007). For example, Daniels *et al.* (2011:158) identified the “diversity of national economies that exist within the EU”; this mirrors the above findings as to the differing *space* licensing regimes within the EU. The institutional differences are significant because, in the face of increasing global competition, a favourable regulatory system can generate a competitive advantage for satellite operators (Griffiths and Zammuto, 2005: 823).

5.6.2 Section Overview

This section has outlined how the *space* licensing process is managed by national governments, but influenced by supranational bodies. This demonstrates a polycentric governance system, with a regulatory form (Cooper and Fox, 1990; Kontopoulus, 2003; Jessop, 2011). The section also identified the national variations in licensing regimes and illustrated how favourable regulatory systems can generate competitive advantages (Griffiths and Zammuto, 2005).

After this stage in a UK satellite mission, the satellite can be launched, as it will have been allocated coordinated orbital spectrum, procured, insured and licensed. However, before the satellite's application can be delivered to market, the satellite or the application requires government support and has to overcome further regulatory barriers. These examples of facilitative and regulatory governance are the focus of the next section.

5.7 Delivery of Satellite-Enabled Applications

This section identifies the facilitative and regulatory governance impacting on the final process of a satellite mission, with particular emphasis on the role that the UK, ESA and the European Commission play in promoting economic activity in the UK satellite applications sector (Mayer and Pickles, 2010:2). This involves an assessment of policy action/inaction, which contributes to explicitly theorising the role of the state, something which has been lacking in global production research (Neilson *et al*, 2014; Smith, 2015).

5.7.1 Further Regulatory Barriers

Prior to the delivery of a satellite-enabled application (specifically telecommunications), the "*landing rights*" of "*every country that satellite signals are going into*" must be obtained (S.Operator2b). A 'landing right' is "the legal authority" for a satellite operator "to connect telecommunications traffic to a country from outside that country" (Chartrand, 2004:28). It is part of local nature of the *space* sector. For global telecommunications operators who provide "*services in countries all around the world*", this can pose a significant regulatory barrier, as there are some countries where obtaining these landing rights is, for want of a more diplomatic phrase, a "*bureaucratic nightmare*" (L.DTHApplications1; S.Operator2b). As with the licensing and registration process, the extent of the 'bureaucratic nightmare' varies between jurisdictions. For instance,

> "*…in some countries you have to apply and pay a small amount of money and then you have a licence that you can frame and put on the wall. In other countries you have to actually go through a more complex compliance procedure*" (L.Operator1b).

This again is evidence of the varieties of capitalism impacting on the legal framework of different jurisdictions. It is also an example of "de-statization of the political system", where there has been a shift of power in regulatory governance, from national state governments to multiple territorial states (Jessop, 2004:14).

In addition, broadcasting licences need to be obtained by DTH providers, since "*if you want to broadcast into a certain territory then you have to get the right licence for that*" (S.Operator3c). There are also other regulations impacting on the delivery of Earth observation applications. For example, pursuant to export security "*some image suppliers cannot sell data to some countries*" (MiDataApplications1a). The UK government also places "*constraints on what data can be provided*" to non-military customers, particularly images from higher resolution satellites (S.DataApplications1). These examples all reinforce the argument that the state plays a critical part in the regulatory governance of the UK *space* sector.

In addition to regulatory governance impacting on the final process of a satellite mission, there are also facilitative forms which have an effect. Section 5.7.2 explores the impact of European-level facilitative governance on UK satellite applications.

5.7.2 European Support for UK Satellite Applications

In addition to ESA procurement projects benefitting satellite manufacturers, ESA projects also create opportunities for value-added service providers. Such providers add value to raw observation data and transform them into deliverable applications. The most recent significant opportunity for these value-added service providers arising from an ESA project is that resulting from the Sentinel One and Two missions, launched in 2014 and 2015 respectively. These missions are part of ESA's Copernicus programme, aiming to achieve an "autonomous, multi-level operational Earth observation capacity" (UNISDR, 2015):

> "*Sentinel One and Two will orbit from pole to pole and be 180 degrees opposite to each other and go round in a constant plane, which means that every six days between the two of them, they will have been able to photograph every square inch of the planet*" (S.GovResearch1).

It is intended for there be a further four Sentinel missions. Whilst each mission will monitor a different aspect of the Earth, collectively they will provide a huge dataset for value-added service providers to "use and develop" (MiDataApplications2). Most significantly, this data will be free, since there is a "*perception that if tax payers have paid something, they have already paid for it"* (MiDataApplications2).

ESA's 'free data' policy is a recent change, as "*previously they* [ESA] *thought it was important to try and recoup the costs*" of its "*incredibly expensive*" satellites by charging for the use of its data (MiDataApplications2). This switch is significant, as it marks a change from policy inaction to policy action in the facilitative governance of the UK *space* sector. The impact of this change has been positive for service providers in creating opportunities, but negative for satellite operators:

> "*…it's certainly killed some businesses… so* [L.Prime2] *set up a service arm… and I'm not sure what their resolution is, maybe five metres, but anyway their business is dead"* (L.Prime1c).

The business of satellite operators has been adversely impacted because free data from ESA is something they cannot compete with:

> "*…if I invest £20 million in a satellite, I can sell the data for £1000 a time and it works. If you are in a market where there is free data that is roughly the same then that doesn't work*" (GovFacilitator2a).

However, this has not 'killed business' for all satellite operators as those who produce higher resolution data (20cm for example) remain competitive and distinguished (GovFacilitator2a). Therefore, ESA's policy action has benefitted some industry stakeholders, whilst negatively affecting others. For example, in the case of the lower resolution satellite operators, policy inaction by ESA would have been preferable to policy action, in light of ESA products now competing in the market. These varying impacts are a significant contribution to the global production literature, which has rarely placed the impact of policy action/inaction in the "foreground" of research (Neilson *et al.*, 2014:3).

5.7.3 UK Government Support for UK Satellite Applications

The UK government's R&D support has also created opportunities for value-added service providers, as government grants (via Innovate UK) encourages technological innovation in UK satellites and thus the delivery of more advanced satellite applications:

> *"We look at thematic areas where we see high profile growth, high potential in the sector and then we look at where the barriers to growth are, or the potential for emerging technologies and targeted investment"* (GovFacilitator1c).

This includes 'innovation vouchers' of £5,000 given to SME's so they have the "*money to go and speak to a University of someone in the sector*" and drive their innovation (GovFacilitator1c). This is an example of facilitative governance, since more advanced applications encourage market creation and attract investment (Mayer and Pickles, 2010:2). The UK government also facilitates economic activity by strategically procuring satellite-enabled services, such as: "*environmental monitoring*", "*satellite navigation programmes*" and "*driverless, autonomous vehicles*" (GovPolicy3b). This is all part of the UK Space Agency's 'Space for Smarter Government Programme', which is specifically "*designed to help businesses get some of their products and services into governments*" (GovFacilitator1b). Such a programme stimulates the market by providing a customer for the satellite operators, whilst also attracting further investment through demonstrating to other customers the UK Space Agency's confidence in the application:

> "*…you can't expect a company to innovate a new transport thing for local governments and then sell them in Africa first because they will just ask if you have sold any of these in the UK and you haven't then you look a bit odd, why are you not selling these in your domestic market first, which is closest to home and where you understand it best*" (GovFacilitator1b).

This associated spillover is evidence of a 'government spending multiplier', for instance, an increase in GDP in response to an increase in government expenditure and investment (Ramey, 2011; Kraay, 2010; Christiano *et al.*, 2009).

Another important facilitative role played by the UK government is the "development of linkages between firms" in the upstream and downstream sectors of the industry (Raco, 1999:959). These links facilitate the delivery of satellite-enabled applications by encouraging a feedback loop between the satellite manufacturers and end-users, helping to ensure that UK applications meet market requirements. There are "*quite a few organisations, like the UK Space Agency and Innovate UK",* which are involved in developing these links, with the Satellite Applications Catapult Centre playing a central role (GovFacilitator1b).

The Satellite Applications Catapult Centre is based in Harwell, near Oxford and was established in May 2013. It is an independent innovation and technology company created by Innovate UK (a non-departmental public body sponsored by the UK government), "to foster growth across the economy through the exploitation of *space*" (SA, 2016). The Applications Catapult is one of eleven Catapults across the UK (each focussing on different industrial sectors) and concentrates on "*joining up the science base with the commercial satellite business*" by helping firms overcome any networking barriers (GovFacilitator2a). In doing so, the Satellite Applications Catapult Centre "*builds new supply chains*" and, whilst facilitating the delivery of satellite applications, influences the organisation of production (GovFacilitator2d).

The impact of the Satellite Applications Catapult Centre is dependent on its two-way relationship with industry, as it engages in a "*real, open dialogue*" with UK satellite firms in identifying the relevant networking barriers and any other policy needs (GovPolicy3b). These exchanges also take place within the UK Space Agency, as explained by one of the large manufacturing primes:

> "*We get involved with consultation stuff… we have regular meetings with the Agency where we will try and influence policy to our benefit or help them try and understand industry requirements*" (L.Prime2a).

Similarly, the other large prime has "*a dedicated team that works very closely with the government*" (L.Prime1d). However, these experiences are not shared by smaller satellite companies, as the capacity to influence government decisions depends largely on 'corporate power' (Henderson *et al*, 2002; Mahutga, 2014). Corporate power is proportional to a firm's "control of key resources" (physical, political, economic, social and technological) and typically relates to firm size (Dicken *et al*, 2001:93). Nevertheless, the UK government argues that it does "*not want to be seemed to be lobbied by the larger players*"; it also listens to the UK Space Trade Association and Steering Board, which work out "*what the collegiate community wants*" (GovPolicy3d; GovPolicy4). Therefore, a 'heterarchial' governance system is in place, where "lower level units" have relationships with "higher-level centres" (Ansell, 2000:306).

The role of the UK government in facilitating the delivery of satellite applications alongside ESA and the European Commission is significant. It again demonstrates a multi-level governance system, where both national and supranational actors are involved. The research analysis also highlighted the involvement of private actors (large satellite firms), as they influence policy action through consultation with the UK Space Agency. Lobbying such as this takes place in a variety of industrial sectors, ranging from the energy sector (Markussen and Svendsen, 2005; Knight, 2011), to the alcohol industry (Hawkins and Holden, 2014). The significance here though is that it is evidence of a heterarchial governance system, impacting on the UK *space* sector (Ansell, 2000).

5.7.4 Section Overview

This section has identified examples of both facilitative and regulatory governance. First, further regulatory barriers impacting on the delivery of satellite-enabled applications were outlined. This showed evidence of "de-statization" involving multiple sites of regulatory governance (Dixon, 2011:194), due to the "multitude of institutional spheres" which satellite projects may involve (Jessop, 2004:14). Second, the dual role of national and European policies in facilitating the delivery of UK satellite-enabled applications was identified. The mutual involvement of both spheres of governance, alongside the influence of private actors, demonstrated a polycentric governance system, which impacts the final part of a satellite mission. These findings, along with a summary of the other four processes explored in this chapter, are outlined in Table 5 below.

Table 5: The Governance of Five Processes that Precede a Satellite Application's Delivery to Market

Satellite Production Process	**Regulatory Governance**	**Facilitative Governance**	**Scales of Governance** Multiple centres of decision-making?
Allocation of orbital slot and spectrum	To apply for an orbital slot and spectrum, satellite operators are obliged to follow a three-step process: (i) Advance Publication of Information; (ii) Coordination Process; and (iii) Notification of Frequency Assignment (see Section 4.3.2).		- Supranational ITU legislation. - National enforcement of the global regulations. - Private influence over national regulations through jurisdiction selection.
Procurement	The *juste retour* principle regulates who the prime manufacturer can procure as their suppliers. This is evidence of how a facilitative form of governance (procurement opportunities) can also be a regulatory form.	- European Procurement projects. - National R&D support extending the technologically possible.	- European public procurement rules (ESA's *juste retour*). - National export regulation, management of European involvement and R&D support. - Private lobbying by large firms for particular projects and policies.
Satellite Insurance	A minimum liability insurance is enforced by the nation states, in response to the Convention on International Liability for Damage Caused by Space Objects (1972).		- Supranational Liability Convention (1972) and Article 7 of the OST. - National enforcement of minimum liability insurance. - Private insurers set premiums and encourage manufacturers to mitigate risks. - Private satellite operators choose whether they want damage insurance.
Obtaining a *Space* Licence	A *space* licence is required before a satellite can be launched and an operator can enter the market.		- Supranational: The OST imposes an international obligation on the UK Government, for a duty of care in managing what it licences. - Nation States have their own licensing process which varies between jurisdictions.
Delivery of satellite-enable application	Data and broadcasting regulations which limit the satellite-enabled applications delivered to market.	- Public procurement projects providing data for value-added services. - National governments stimulating market demand and linking relevant agents for the sale of applications.	- European facilitative governance. - National regulatory and facilitative governance. - Private Firms influence through political lobbying.

Source: Author.

5.8 Conclusion: The Governance of the UK *Space* sector

This chapter has provided a necessary insight into the governance of the UK *space* sector, which effects the organisation and competitiveness of satellite production projects. This is critical, as an understanding of the *space* sector requires an understanding of its complex regulatory framework and reliance on government support. Analysis was divided between five key processes, all of which precede a satellite application's delivery to market. This section summarises the key research findings from the analysis of these five processes and links the findings to the chapter's three aims. Contributions to the literature are also reiterated with links made to the discussion which follows in Chapter 6.

5.8.1 Summary of Key Findings on the Governance of Five Key Processes

The first of five processes to precede a satellite application's delivery to market is the allocation of an orbital slot (if a geostationary operator) and spectrum. Analysis of this process found that the dominant form of governance impacting on this process is regulatory (Table 5). In addition, the governance is 'multi-level', occurring on a global (ITU) and national (Independent Regulatory Authority) scale (Venet, 2012). The relationship between these two scalar actors is non-hierarchical, as the ITU behaves more as a gateway rather than a gatekeeper, countering the argument in the literature that "national policy instruments" are being "eroded by supranational powers" (Mclaughlin and Maloney, 1999:1). Meanwhile, nation states are responsible for enforcing the regulations concerning slot and spectrum allocation on satellite firms. Each state interprets ITU regulations differently, which has led to jurisdiction selection as operators locate their headquarters in countries which enforce the regulations in a favourable way (Clark and Monk, 2014). The commercial operators were also found to govern the use of *space* through orbital slot markets, highlighting their role as non-state actors in the governance of the UK *space* sector (Wang, 2009:438).

The second key process to precede a satellite application's delivery to market is satellite procurement. This process is framed by legal norms emanating from both the European and national level (Venet, 2012). These findings highlight the impact of ESA and, increasingly the European Commission, on the UK *space* sector. As shown in Table 5, there are examples of both facilitative and regulatory governance which impact on this process, with overlap between the two forms.

The third process is satellite insurance. This involves supranational, national and private actors (Table 5). A consideration of satellite insurance is significant, as it furthers the political-economic debate of how governance is neither public nor private (Bennet, 2000; Bartley 2007; Black, 2001; Grabosky, 2013). It also identified the metagovernance by supranational conventions (i.e. OST and liability conventions) on national laws (i.e. minimum liability level), as well as partnership between the UK government and private insurers (Bennet, 2000; Bartley 2007; Black, 2001; Grabosky, 2013). These interactions are evidence of the heterarchial relationships between the supranational, national and private actors.

Fourth, the process of obtaining a *space* licence is undertaken. Like orbital slot and frequency spectrum allocation, this process is managed by national governments, but influenced by other national institutions and supranational bodies (Table 5). This evidences a polycentric governance system, with a regulatory form (Cooper and Fox, 1990; Kontopoulus, 2003; Jessop, 2011). Satellite licences also vary between national contexts, influencing operators' location decisions and highlighting the continued importance of place (Neilson and Pritchard, 2009).

Finally, satellite-enabled applications are delivered to market. The analysis of this process focused on the facilitation of applications at the national and European level as well as the further regulatory barriers in place. There are multiple sites of these regulations (Table 5), showing evidence of "de-statization" (Dixon, 2011:194). There is also a dual-effort by national and European actors in market facilitation, which demonstrates a polycentric system.

Table 5 brings together the findings outlined in this sub-section to highlight the similarities and differences between the forms and scales of governance impacting on the five key processes. The next sub-section draws on these comparisons as it outlines features of the overall governance of the UK *space* sector, by addressing the chapter's three aims.

5.8.2 Overall Governance of the UK *Space* Sector

The five key processes which precede the delivery to market of a UK satellite application are governed by global, European, national and private actors (Venet, 2012). The result is a multi-level, polycentric governance system, with "many centres of decision making" (Ostrom *et al*, 1961). These different scalar actors all interact in a heterarchy, with "lower-level units" (such as satellite operators) having relationships with "higher-level centres" (national and European actors) (Kontopoulus, 2003; Ansell, 2000:306). This interaction occurs within the five processes, but also between them. For example, the benefit arising from an internationally agreed orbital slot (i.e. actually being able to launch the satellite into that position), is dependent on a nationally assigned *space* licence and privately negotiated insurance policy and vice versa.

The nation state plays a central role in this process, by enforcing regulations and facilitating market growth, whilst EU procurement rules and UN treaties set the "the ground rules" for governance and regulatory order (Jessop, 2011:119). This highlights the importance of UK government involvement to the competitive success of the UK *space* sector, whilst emphasising the need for it to engage and cooperate with supranational and other national stakeholders. This is necessary, as without international agreement, national decisions could be undermined or overturned. It is also a significant contribution to the literature because, whilst there has been "some consideration of the institutional and regulatory contexts within which global production networks operate", clear "theorisation of the state's role has been somewhat lacking" (Smith, 2015:291; Neilson *et al.*, 2014:3). Furthermore, it counters Nadvi's (2008:331) argument of how global scales of governance are "increasingly undermining the regulatory powers of national governance". It is important to appreciate however, that "governance regimes are seen as temporary, situation-specific stabilisations" (Smith *et al*., 2002). Therefore, this governance structure may evolve and change over time.

As highlighted in Table 5, the dominant form of governance impacting on the UK *space* sector is regulatory. This is significant, as whilst facilitative governance focusses on the promotion of economic activity, regulatory governance imposes limits on the "scope of private activities" (Mayer and Pickles, 2010:2; Cheng, 2015:382). Consequently, the impact of governance on the industry is more restrictive than enabling. However, the forms and also scale of governance varies between the different stages of UK missions. The division of "separate but related tasks" is a continuation of the thesis's PPT approach and addresses the gap in the literature as to how governance can vary between different stages of production (Bryson, 2009:37). In addition, at a single stage of production, the impact of governance varies between different actors. For instance, ESA's Sentinel mission will create opportunities for value-added service providers, but generate unwanted competition for satellite operators who produce low resolution earth observation imagery.

5.8.3 Links to Chapter 6

Throughout this chapter, connections were made between the governance of the industry and the organisation of production, addressing Jones's (2014:608) call for the two theories to be better integrated. For example, as part of the licensing and insurance process, UK manufacturers and operators must comply with certain financial/technical requirements, which are passed onto their suppliers. Meanwhile, the emergence of an 'orbital market' means that 'first-movers' hold the power and may, or may not, sell their orbital positions and spectrum to other operators.

The next chapter explores these links, whilst also providing a detailed analysis of the organisation of and relationships between production tasks and projects (Gereffi and Mayer, 2005:39). The different relationships are determined by industrial governance, which is as significant as market governance in impacting the competitiveness of the UK *space* sector (Gereffi and Mayer, 2005).

CHAPTER 6

ORGANISATION OF PRODUCTION AND BSRs

IN THE UK *SPACE* SECTOR

6.1 Introduction

The previous chapter provided insight into the market governance of the *space* sector on a national, European and international scale. This was important for developing an understanding of what shapes both the organisation and competitiveness of the UK satellite industry. Understanding the UK *space* sector's 'industrial governance' is also important in characterising its economic geography; industrial governance is part of the organisation of production and concerns the nature of ties or relationships between buyers and suppliers in production projects (Gereffi and Mayer, 2006; Nadvi, 2008; Bair and Palpacuer, 2015). The varying nature of buyer-supplier relationships (BSRs) at different phases of a satellite mission is thus the focus of this chapter. A 'mission' is the term used in the *space* sector to describe when linked production projects (i.e. manufacturing, operating and the provision of applications) come together to form a complete overall project.

The common approach to framing an analysis of BSRs is the application of a typology, since it encourages "a variety of different relationship characteristics" to be considered simultaneously (Cannon and Perrault, 1999:440). Consequently, the global value chain (GVC) governance typology (Gereffi *et al.*, 2005) provides a useful "skeletal framework" for this chapter to conceptualise the character and structure of BSRs in the UK *space* sector (Cannon and Perrault, 1999:451). The typology frames the analysis by pairing empirical evidence of procurement moments in the UK *space* sector with the five BSR types. The GVC governance typology was chosen because it: (i) effectively highlights organisational structure and power dynamics of BSRs; (ii) is an accessible but not oversimplified tool; and (iii) there are consistencies, between the variables and types in the GVC governance typology and alternative typologies in the business management and marketing literature (Gereffi *et al.*, 2005; Ponte and Sturgeon, 2014; Saccani *et al*., 2014).

Despite the benefits and proven usefulness of the typology there are criticisms of the typology which require the following adjustments be made: (i) focussing on more than a single procurement moment; (ii) distinguishing between captive-buyers and captive-suppliers; (iii) prioritising the 'degree of coordination' and 'power asymmetry' of BSRs above ability to 'codify information and supplier capability'; and (iv) considering external governance factors. There also other factors (namely buyers and contracts, technology, time and geography) and industry specific features (i.e. satellite orbit constraints for instance) which impact on BSRs and need to be accounted for. These adjustments and identification of industry specific features will develop the GVC governance literature further. The chapter also highlights the overlap between the 'five types' (Gereffi *et al*., 2005), as there are exchanges in the UK *space* sector which have characteristics of more than one type of BSR. Additionally, the spatiality of the BSRs are identified, comparing the exchanges that require geographic proximity with those that can be more dispersed. The chapter also makes a valuable contribution to the sector, as understanding the interactions between various agents in the UK *space* sector is necessary for formulating appropriate policy responses (Chapter 8, Section 8.5).

This chapter divides analysis between the sale of satellites and satellite-enabled applications because of the differences in production tasks and firms involved. However, any links and feedback loops between the two sales are also identified, since the output of one is a core necessary input for the other (Chapter 2, Figure 2.2). Section 6.2 outlines the division between the two sales in more detail, through explaining the structure of the industry and what this means for the analysis of its BSRs. Section 6.3 then proceeds to explore vertical integration and upgrading in the UK *space* sector (i.e. hierarchical type BSRs), where more than one production project (i.e. manufacturing, operating and service provision) is performed by a single company. It highlights why this type is uncommon in the UK *space* sector, and thus the relevance of the other, external types of BSRs which link different companies. Section 6.4 and section 6.5 then use the GVC governance typology to explore the BSRs involved in the sale of a satellite and satellite-enabled applications. The final section focusses specifically on the interactions and comparisons between different BSRs (linking different production projects). This provides a more complete overview of the nature and structure of relationships governing civil, commercial and military satellite missions.

6.2 Structure of the Industry

The *space* sector encompasses three linked sub-sectors that manage their own production projects, subordinate projects and tasks (Chapter 4). The three sub-sectors are satellite manufacturing, satellite operations and satellite applications. They are independent, yet their production projects are linked by BSRs. In a complete satellite project (or mission), there are three related production projects involved: (i) manufacture of the satellite; (ii) operation of the satellite; and (iii) satellite-enabled application provision. These projects are each delivered in different sectors of the *space* sector and consist of multiple production tasks. The projects are linked by the following BSRs: (i) sale of the satellite (linking manufacturing and satellite operation); and (ii) sale of satellite-enabled application (linking satellite operation and application). The BSRs vary depending on whether the satellite is intended for commercial, institutional or military purposes. Additionally, they differ between telecommunications, Earth observation and navigation satellites, since the form of the satellite-enabled applications (whether business-to-business or business-to-consumer) and therefore, the associated relationship, varies between types of satellites. Examples of different applications include: transponder capacity for a direct-to-home television broadcasting (business-to-consumer); a data package of Earth observation imagery (business-to-business); and a positioning signal for satellite navigation (business-to-consumer). The two BSRs are identified in Figure 6.1 and are the focus of this chapter.

There are other important BSRs within the production projects, including those that supply components for a satellite's manufacture. However, these more generic BSRs across manufacturing (see Tonts *et al*., 2012; Kim *et al*., 2011; Nyaga *et al*., 2010; Tangpong *et al*., 2008; Rosetti and Choi, 2005; Hanson *et al*., 2005) and service projects (see Rapaccini, 2015; Saccani *et al*., 2014; Tokatli, 2013; Mayer and Gereffi, 2010; Tokatli, 2007), have already been investigated and are well understood in the literature. In contrast, despite the literature identifying that there are varying relationships at different points along a value chain, there is an absence of empirical work comparing BSRs within the same chain, but at different stages of production (Gereffi and Lee, 2012). Comparing the two BSRs which link the satellite manufacturing, operations and applications projects provides a structured approach to addressing this research gap.

The next section focusses specifically on vertical integration and upgrading (hierarchical type BSRs), where more than one production project (manufacturing, operating and service provision) is performed by a single company.

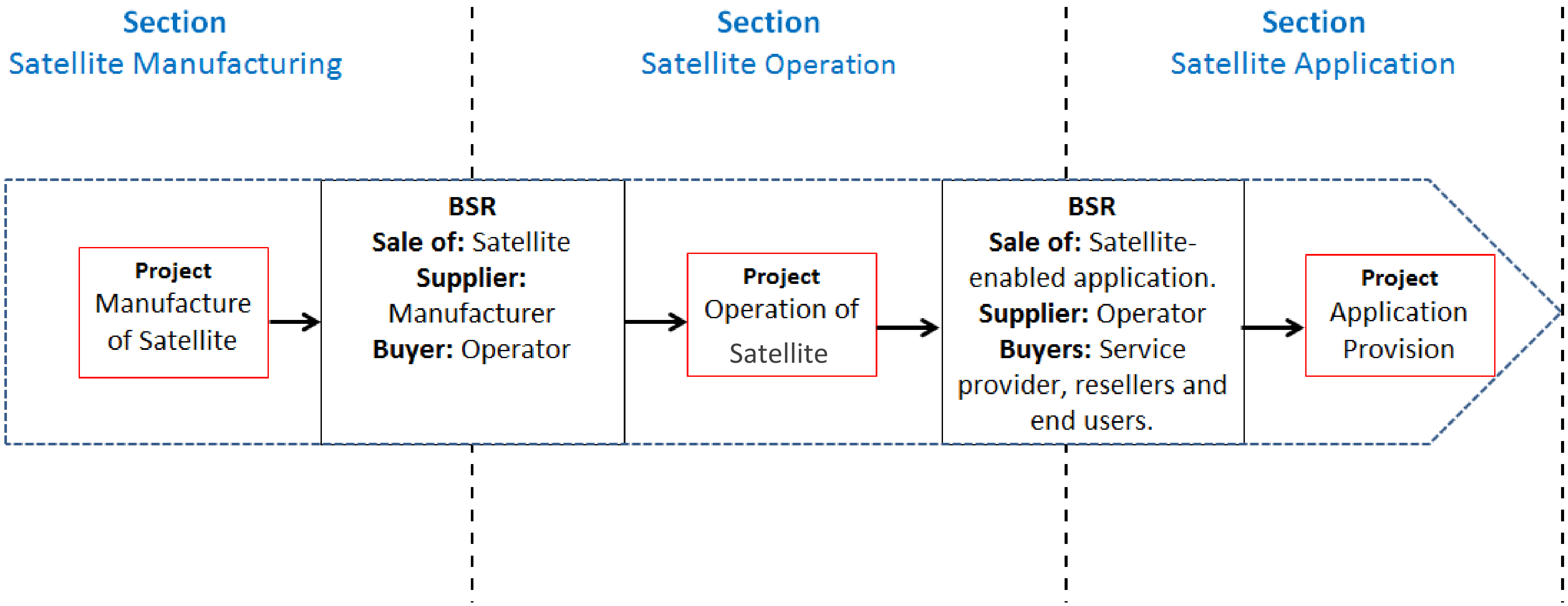


Figure 6.1: Buyer Supplier Relationships (BSRs) and Structure of the *Space* sector.

Source: Author.

6.3 Hierarchical Forms of Industrial Governance in the UK *Space* Sector

This section explores vertical integration and upgrading in the UK *space* sector, focussing on a situation where more than one production project (i.e. manufacturing, operating or application provision) is performed by a single company. The in-house projects are linked by internal supply relationships and the character and structure of those relationships are identified as the hierarchical type BSRs in the GVC governance typology (Ponte and Sturgeon, 2014). A hierarchical type BSR involves the management of in-house linkages that are explicitly coordinated, with complete control over them by the lead-firm (Sturgeon *et al*., 2008). This section provides a theoretical outline of vertical integration and upgrading along with outlining the barriers to both in the UK *space* sector. This demonstrates the relevance of the other types of BSRs which link firms that work in different sub-sectors of the industry.

6.3.1 Vertical Integration in the UK Satellite Industry

'Vertical integration' is the term used for a situation where a firm brings production in-house, which would otherwise be outsourced to an external supplier. This section focusses specifically on evidence of UK satellite operators having vertically integrated manufacturing projects or application providers bringing operating tasks in-house. There are a number of reasons why a lead firm would vertically integrate a production project. Firstly, when products are complex they require non-standardised inputs and specifications which cannot be codified (Gereffi *et al*., 2005). This means lead firms rely on an exchange of tacit knowledge with their suppliers, which demands frequent, face-to-face contact. However, this level of interaction may be difficult to maintain with an external supplier and instead may only be achievable in-house. Secondly, the complexity of the product can mean it is difficult to find a supplier who is competent enough, leaving the lead firms with little choice but to vertically integrate additional production projects (Gereffi *et al.*, 2005). Thirdly, if the supply of the product is time-sensitive, then in order to avoid high coordination costs, activities are brought in-house. Finally, vertical integration ensures the control of rights over resources, such as intellectual property (IP) (Gereffi *et al.*, 2005). For instance, if an operator were to manufacture its own satellite, it would solely own the IP. It would also have a greater degree of freedom to experiment with the satellite's design and have the opportunity to feedback knowledge from its upstream involvement "*into their downstream work"* (S.SystemsManufacturer1b).

Despite the potential benefits associated with an operator manufacturing its own satellite (i.e. control of IP, freedom with the design, knowledge feedback), all UK-based operators outsource their manufacturing projects to external firms. There are three key reasons for this. First, manufacturing is a "*completely different job*" and not in keeping with an operator's business model: "*building satellites is slow, very labour intensive and the margins are not fantastic, so it wouldn't really fit*" (S.Operator1b). As a result, UK operators tend not to vertically integrate manufacturing projects, but instead manage external supplier relationships and focus on their "own areas of competence" (Gereffi *et al.*, 2005:81). Second, competitive tendering is more cost efficient than vertical integration, since competition "*forces the suppliers to invest in new technologies, which reduce their costs*" (M.Operator1a). Finally, operators lack the "*scale or capability to manufacture a satellite*" (L.Operator1d). The 'scale' refers to the facilities and labour force required during manufacturing as well as that which is required to be maintained once a satellite is delivered. For instance, as one participant explained:

> "*We need a new satellite every six years, so to set up a whole manufacturing facility just for that… there would be twelve to eighteen months of actual physical*

> *work to build the satellite and then the place would be dormant for five years*" (L.Operator1c).

Similarly, if application providers were to vertically integrate satellite operating projects then they could reap multiple benefits, including: ownership of a valuable asset; having greater freedom in specifying their data needs; and being "*in control of their own destiny* [independent of external operators]" (M.Operator2). Consequently, "*new entrepreneurial companies like Planet Labs and Sky box* [offering different technology solutions]" are exploring the viability of delivering "*the whole thing*". For instance, these entrepreneurial companies owning and operating a satellite, whilst delivering a satellite-enabled application (GovPolicy3d). However, satellite operating is an expensive business, with high-costs associated with the satellite infrastructure, ground stations, launch and insurance. Additionally, obtaining orbital slots, coordinated frequency spectrum and a *space* licence are complex and competitive processes (Chapter 5, Section 5.3), which existing UK application providers have insufficient resources for, in terms of both finance and capabilities. Therefore, external BSRs link separate operating and application firms.

This short sub-section has outlined the barriers to the vertical integration of production projects in the UK *space* sector, highlighting the relevance of external type BSRs. The following sub-section develops this further, by exploring the barriers to upgrading in the industry.

6.3.2 Upgrading in the UK *Space* Sector

In addition to the vertical integration of their suppliers' tasks and projects, firms are often motivated to shift their product focus towards higher value-added activities (Saccani *et al*., 2014; Neely, 2008; Davies, 2004). This is known as 'functional upgrading' and is achieved by firms "utilizing knowledge and experience gained in another area" (Tokatli, 2013:1000). Upgrading results in a single firm being responsible for more than one production project because they maintain their existing activities alongside their new higher-value projects (Blazek, 2015). The economic geography literature has focussed primarily on upgrading in the apparel industry, specifically in emerging developing markets (Tokatli, 2013; Bair, 2006; Tewari, 2006; Smith *et al.*, 2014), where "low-cost manufacturing suppliers" have moved 'up' global value chains to higher-value activities (such as design) (Ivarsson and Alvstam, 2010:731). It is the case that suppliers in the UK *space* sector are very different to those in the apparel industry, as satellite manufacturers and application providers are far more high-tech and high-cost. Similarly, the value chain for a satellite mission is more local than global, with defence restrictions and the complexity of the satellite technology limiting the involvement of emerging developing markets (unlike in the apparel industry). Nevertheless, there are examples of firms upgrading or shifting towards higher-value activities in the UK *space* sector

Upgrading is relevant to this section because additional higher-value activities are linked by internal supply relationships that have the character/structure of the hierarchical type (Ponte and Sturgeon, 2014). However, there can be "discouragement and even obstacles" to upgrading (Tokatli, 2007:68), as it can be in the buyer's interest to prevent a supplier from becoming a competitor (Rosetti and Choi, 2005). Additionally, the potential for functional upgrading is dependent on a range of factors (Ivarsson and Alvstam, 2010). For example, "capabilities and ambition of the supplier", and whether they are capable of dealing with the complexity of the production project (Blazek, 2015:8). This sub-section explores these barriers to upgrading, which minimise hierarchical supplier-relationships in the UK *space* sector.

Paradigm Secure Communication was established in 1999 by the largest UK-based satellite manufacturing prime and operates the Skynet 5 satellites for the Ministry of Defence (MOD) (London Economics, 2015). It is the best example of a UK satellite manufacturer ‘upgrading’ to an operating project, on the basis that satellite operating has greater profit margins than satellite manufacturing and is thus a shift to a higher value-added activity (see Table 6.1).

Table 6.1: Comparing the Profitability of Satellite Production Projects.

Production Project	**‘Earnings before interest and taxes’ (EBIT) Average Margins**
Satellite Manufacturing	2-8%
Satellite Operating	30-40%
Satellite-enabled Application Provision	0-15%

Note: EBIT average margins are the sub-sectors’ earnings before interest and tax as a percentage of their net sales. The higher the margin the more profitable the project.

Source: OECD (2012:44).

Nevertheless, the Paradigm manufacturer only “*somewhat reluctantly got into services* [Paradigm]” when it discovered that the MOD was not willing to buy its satellites outright, leaving them little option but to try and “*sell the satellite service*” (L.Prime1c). Therefore, it was not that the prime made a premeditated decision to upgrade to a higher value-added activity, but that market pressures forced it to expand its product range. It was “*always in the back of* [its] *mind that* [it] *wanted to sell a satellite*” (L.Prime1c).

Customer pressure is a factor influencing upgrading that has not been identified in other empirical studies and therefore is a valuable contribution to the literature (Ivarsson and Alvstam, 2011; Tokatli, 2013; Bair, 2006; Tewari, 2006). The pressure also helps explain why the firm's service arm has not developed beyond the military market, since the motivation to upgrade did not displace its priority to manufacture and sell satellites. For example, it "[does not] *try and compete with the more well-established telecom operators*" but instead sticks to its niche markets (L.Prime1c). Consequently, this example of upgrading in the military satellite market is not necessarily representative of the organisation in the commercial sector.

However, there are examples where manufacturers operate satellites on behalf of commercial customers:

> "*So a company in China wants all the capacity to map China for agricultural purposes and we will own and operate those satellites... So rather than us selling the satellite to them, we will operate the satellite*" (L.Prime2b).

These operating projects are in addition to other product related services that the manufacturers provide to their customers, such as backup support through information exchanges. Product maintenance is not a related service as it is not presently possible to perform this service in *space.* The additional benefit to the manufacturer in operating the satellite is that *"the service business can provide feedback to the satellite design team"* (L.Prime1d). Examples of valuable feedback include the required image resolution and frequency spectrum (GovFacilitator2b). It is important to note that commercial operating is only a small part of the UK satellite manufacturers' business and is limited to smaller and cheaper "*Earth observation* [satellites]" (L.Prime2b). Meanwhile, "*very big and very expensive*" geostationary communication satellites are operated by other "*big commercial companies*" (L.Prime2b). Commercial operating is not a core part of UK satellite manufacturing, contributing only "*5%, maybe less*" of their profits (L.Prime2c).

There are several reasons why UK satellite manufacturers do not focus more on operating. First, manufacturers must be "*careful not to put their* [satellite operation] *customers out of business*" by competing with them, since this would be detrimental to the core part of their business (i.e. selling satellites). Second, compared to satellite manufacturing, operating is a very different management and coordination activity. This is mainly due to the different timescales. Satellite manufacturing contracts typically lasting as long as four to five years, whereas operating contracts *"might be on a weekly basis or even shorter"* (L.Prime2c).

Satellite manufacturing and operating are simply "*two very different things… like building and driving a car*" (M.Prime1a). These differences mean that the two production projects require very different resources (namely skills, knowledge and finance), with the result being that manufacturers do not necessarily have the capabilities or finance to operate or market the bandwidth/satellite data stream:

> "*Big manufacturing companies cannot just change their spots. Our DNA is manufacturing. We know how to operate satellites but we are not a service provider. Our skill set, our infrastructure and our culture, all developed over decades, makes us what we are*" (L.Prime1c).

The Paradigm contract was only possible because the manufacturing prime "*went to an established provider*" that had the in-house expertise (L.Prime1c). This counters the simplification in the literature that complex products with non-standardised inputs and specifications are often brought in-house because lead firms are unable to codify information and find a competent supplier (Gereffi *et al.*, 2005). With Paradigm, the operating and manufacturing undertakings of the firm are also so different that "*they are treated almost as separate companies*", where "*there is friendliness, but communications aren't always what they should be*" (GovFacilitator2b). Therefore, even when a firm manufactures and operates, the hierarchical relationships which link the production projects are not always as close as the GVC governance typology suggests (Gereffi *et al*., 2005). Finally, the separation of the upstream (satellite manufacturing) and downstream (satellite operating and application delivery) sectors of the industry "*is kind of entrenched now… you have satellite manufacturers and you have operators*" (M.Prime1a). The separation has become an industry convention, defined as "a broad group of mutual expectations", which guide action and provide forms of coordination (Ponte and Gibbon, 2005:6). The convention has caused path dependency, whereby satellite manufacturers are unable to "shake free of their history" and develop beyond their "established ways of doing things" (Martin and Sunley, 2006:400). Consequently, satellite manufacturing and operating remain two very different parts of the *space* sector.

Overall, evidence of UK satellite manufacturers upgrading to operating projects is sparse, suggesting that BSRs other than the hierarchy type are more common in the industry. Similarly, the research identified limited evidence of operators upgrading their activities to include downstream applications. The operators do deliver some applications to demonstrate the functionality of their satellites to their customers:

> "*…we are trying to promote the use of satellite services. So we have to go out and demonstrate things to the country and the users*" (M.Operator1a).

For example, an Earth observation operator may produce its own satellite images, to demonstrate to its customers the quality of the data captured by its satellites, for instance, the resolution quality. However, this is "*not profit driven*" and constitutes a small part of its business (M.Operator1a). One of the participants explained how the delivery of satellite-enabled applications is more of a "*retail businesses*", thus also very different from satellite operating (L.Operator1b). Therefore, UK operators are not always capable or want to be involved with value-added services: "*they are less profitable, they acquire more people, they are more localised and more complex*" (L.Operator1b). Instead, they "*would rather partner with other companies*" who are the "*experts in what they do with the data*" (L.Prime2b). Consequently, there is a downstream division between the companies that operate and provide satellite-enabled applications. As with manufacturing and operating projects, they too are linked by types of BSRs other than hierarchy.

6.3.3 Section Overview

This section has investigated the frequency of internal supply relationships (i.e. hierarchical type BSRs) linking production projects in the UK *space* sector. It focussed on examples of firms vertically integrating and upgrading projects, as in those circumstances they perform more than one key production project and coordinate them with hierarchical relationships. The section first outlined the motivations behind vertical integration and upgrading, including control over resources, access to higher value-added activities and market pressure (Sturgeon *et al*., 2008; Saccani *et al*., 2014:226; Neely, 2008; Gereffi *et al*., 2005). These associated benefits for firms suggested that upgrading and vertical integration of key production projects may be common in the UK *space* sector. However, the section identified multiple obstacles faced by firms in this regard.

The obstacle which hindered all three groups of firms' vertical integration and upgrading is the difference between the production projects. Those differences mean that the firms' existing capabilities and resources (namely skills, knowledge and finance) are often insufficient for them to diversify their projects into other sectors. Therefore, a separation between the upstream (i.e. satellite manufacturing) and downstream (i.e. satellite operating and application delivery) sectors of the industry have become the norm. This means that even if differences could be overcome, there is the barrier of path dependency (Martin and Sunley, 2006). Additionally, the differences mean that if a single firm does perform more than one key production project, as with the Paradigm example, then the departments for each production project will be "*treated almost as separate companies*" (GovFacilitator2b). Therefore, hierarchical relationships which link key production projects in the UK *space* sector are more complex than, and not always as close as, the GVC governance typology suggests (Gereffi *et al*., 2005).

Finally, this section has highlighted the barriers to vertical integration and upgrading in the UK *space* sector. Consequently, *space* manufacturing, satellite operations and satellite applications are managed by separate firms, yet linked by external BSRs. Therefore, analysis of the industry's BSRs needs to take into account more than one lead firm and a single procurement moment, as well as BSRs types other than hierarchy.

6.4 Sale of a Satellite

Section 6.3 outlined the barriers to vertical integration in the *space* sector, which makes it uncommon for a single firm to manufacture and operate a satellite. Consequently, satellite manufacturers sell their satellites to operators via a complex procurement process. Depending upon whether the sale is part of an institutional or commercial contract, and on the length of the relationship between the manufacturer and operator, there are varying types of BSRs involved. This section identifies these types of BSRs and the industry-specific complexities relating to the sale of a satellite that affect the BSRs. This section also highlights the difficulty with the operationalisation of Gereffi *et al*'s. (2005) five types, as characteristics of the types can overlap. The analysis is divided between institutional and commercial contracts. First, the BSRs between manufacturers and the European Space Agency (ESA) are discussed.

6.4.1 BSRs Governing the Sale of an ESA Satellite

This sub-section explores the BSRs governing the sale of institutional satellites in the UK. The focus is on satellite missions funded by ESA, as they are the primary European-level governance actor, responsible for the majority of institutional contracts awarded to UK firms (Chapter 5, Section 5.4.2). ESA's satellite projects focus on technological developments, improved access to *space* and scientific advances (Mazurelle *et al*., 2009:156). Consequently, the satellites' designs are often "Europe's first" or "next-generation" technology demonstrators, meaning the satellites are more innovative and the transactions are more complex (ESA, 2016). Therefore, the information exchanged between ESA (as the buyer) and manufacturers is difficult to codify and instead warrants close interactions and two-way exchanges of information. The information exchanged may be grouped into four overlapping stages, which are outlined below. These interactions are not exclusive to ESA contracts, but are typical of all satellite transactions because of the complexity of the technology involved. However, the frequencies of the interactions "*are typically greater*" for a more complex ESA satellite (GovPolicy2c).

First, the buyers, whether they are ESA or commercial operators, and manufacturers work closely on the design of the satellite. The buyers share their mission objectives and "*specify exactly what they want*" (GovPolicy2b), including how many transponders, how much power and the frequency at which the satellite needs to operate (Fortescue, 2003). This is more than 'contract production', where the buyer has "indirect control through the specification of design and product formats" (Smith, 2002:46), since on the basis of these specifications, the manufacturer helps the buyer to "*understand what is possible*" (GovFacilitator1b).

By way of example:

> "*So* [the buyer] *would come to us and say 'right I want this satellite, I need it to do this, this and this for customers, I need it to be in this orbit and I want it to launch then'.* [The manufacturer] *will then say 'well if you want it to do this, it would need this kind of payload and if you want it to do this, then it will need this propulsion system and we need these solar arrays' and then we will go back to them and say 'this is what your satellite looks like, to be able to do what you want to do, this is what you have to buy*" (M.Prime1a).

The buyer has its own team of engineers "*who know spacecraft…how to build, design and how to operate them*" and work alongside the manufacturer's team. The buyer's engineers even "*second guess or challenge the supplier*" on the design if necessary (M.Operator1a). The benefit to the manufacturer of this "*deep engagement*" with the buyer is the "client-specific knowledge" it obtains, which is a "large component of value creation" (Chatain, 2011:78). Meanwhile, the benefit to the buyer is that it can ensure it gets "*a satellite designed and costed out that would meet* [their] *requirements*" (S.Operator3c). Additionally, it contributes to the buyers' service provision, as "*if you know how the payload works you know how to receive it at the other end*" (GovFacilitator1b). To one of the participants:

> "*… not leveraging the manufacturers experience is ridiculous, it is a key resource for any operator to use*" (S.Operator2c).

Once the design has been completed, the manufacturers outsource subordinate projects to a network of suppliers. If an ESA project, these networks are restricted to certain suppliers because of the *juste retour* principle (Chapter 5, Section 5.4.2).

Second, information is exchanged during review meetings regarding project milestones. These meetings include a preliminary design review (PDR) and a critical design review (CDR), where a “*contract change note*” can be issued with changes to the costs and schedule of the project. The CDR “*is realistically the last opportunity to change anything*” but generally a manufacturer does its best to accommodate requests made by its customers “*even after CDR*” (L.Prime1c). There are then several production milestones, between which payment for the satellite is divided: “*there are probably five or six of those throughout the two or three year period*” (L.Prime2b). In addition to the design reviews and project milestone meetings that are formally scheduled at the beginning of a contract, the buyer sits down on a “*weekly or monthly*” basis with the manufacturer “*just to go through how it is progressing*” (S.Operator3c). The buyer’s “*right to have visibility*” of the progress of the project is “*no different to any other business*”, but since the production of a satellite can take “*two and a half to three years*”, it results in particularly “*close relationships*” (L.Prime2b; L.Prime2a).

Third, there is the “*immersive*” stage where the buyer’s engineers spend time at the manufacturer’s facilities, “*on-site, looking and overseeing the process*” (L.Operator1b). The buyer’s engineers “*have permanent project officers at multiple manufacturing sites*”, resulting in “*daily interaction*” between the buyer and the supplier (S.Operator1b). This provides the buyer with the opportunity to “learn about their systems, procedures, and processes in order to improve communication, reduce errors, and enhance capabilities”

(Corsten and Felde, 2004:446). A buyer's motivation for this is partly because of wanting to protect their significant investment, which can be in excess of £250 million. Additionally, satellite manufacturing is "*so complicated*" that it needs the buyer's engineers to "*help solve problems*" using their specific knowledge of the satellite mission (S.Operator1b; L.Prime2a). Therefore, the manufacturer can also learn from the temporary proximity of the buyer, when on-site (Rychen and Zimmermann, 2008). This highlights how "immense advances in transport and communication technologies" cannot always substitute the requirement for geographical proximity (Rychen and Zimmermann, 2008:767). Since:

> "…face-to-face interaction is widely held to be a necessary condition for establishing trustful relations and communicating sensitive, not well-established knowledge and information" (Maskell *et al*., 2006:9).

It also shows how innovation activities and knowledge production can be achieved by temporary proximity; there does not have to be permanent co-location (Rychen and Zimmermann, 2008). This is advantageous for the buyer because it offers greater flexibility on its location and means it does not geographically restrict who it can choose as its supplier. Temporary proximity is possible for large organisations such as ESA and leading commercial operators, as they can afford to move some of their employees to the manufacturer's site (Müller and Stewart, 2016). However, this is more difficult for smaller operators with limited resources.

Finally, a satellite is "*not a kind of sell and forget*" product (L.Prime2b). The sale of a satellite typically involves feedback to the manufacturer on the satellite's functionality. This feedback is known as "*post flight monitoring*" and typically lasts "*for a year or so*" after launch, relaying data on factors such as "*controllability and fuel usage*"

(L.Operator1a). This feedback includes reflections on the life-time of the satellite, which contributes towards future improvements. Such reflections include how a satellite's equipment is affected by its harsh environment and how its "*performance changes and alters throughout its life time*" (L.Prime2b). It helps to identify "*any technical anomalies that come up*" and "*improve the manufacturing processes and the design of those components going forward*" (L.Operator1a). These opportunities for learning and improvements are particularly important to ESA projects which involve 'next generation' technology (Selnes and Sallis, 2003).

The close interaction achieved by temporary proximity and the two-way exchange of ideas during both the design phase and later phases is typical of a relational type BSR (Gereffi *et al*., 2005). However, if 'degree of explicit coordination' and 'power asymmetry' are instead the focal points then the nature and structure of the relationships governing the sale of ESA satellites could also be identified as 'captive'. This relates to restrictions placed on procurement by the '*juste retour'* principal, which places a limit on which companies an ESA contract may be awarded to (Chapter 5, Section 5.4.2), since the value of that contract must be proportional to the share of the budget contributed by the government of the country in which that company is based (ESA, 2016; ERA, 2016; Schmidt-Tedd, 2011). Therefore, an ESA satellite must be manufactured by a prime based in a European country that is significantly contributing to the relevant ESA budget. The procurement principles which govern ESA therefore, lock-out satellite manufacturers that are based outside of ESA-member states (i.e. Boeing in the US). This creates a concentrated market of institutional satellite manufacturers, with stable demand and limited market growth (Bensaou, 1999). In consequence, the buyer, whether it be ESA or an operator with funding from ESA, is transactionally dependent on a select group of suppliers, which have strong bargaining power over it. This is an example of a 'captive-buyer' relationship and contradicts the narrow focus in the GVC governance literature on how buyers coordinate their suppliers in a "top-down process" (Lee and Gereffi, 2015:321). Furthermore, the sale of institutional satellites as a captive-buyer type exchange is a consequence of public governance principles. This finding contributes towards addressing the gap in the GVC governance typology, where the impacts of external governance factors on production projects have been overlooked (Gibbon *et al*., 2008; Rainnie *et al.,* 2011). Additionally, it highlights the overlap between the organisation of production and the governance of an industry, and thus the value of researching both in this study.

Captive-buyer BSRs can have high associated costs, as suppliers are under "*less pressure…to price change*" and drive down their costs (M.Operator1a; L.Prime1c). Additionally, ESA missions do not always involve the most innovative of technologies and suppliers, but instead those that fit politically with their procurement criteria (Chapter 5, Section 5.4.2). Therefore, the captive type BSR governing the sale of an ESA satellite may impact negatively on the price and innovativeness of the satellite. However, as the funder of the project and the exchange party setting the procurement rules, ESA retains a significant amount of power in the relationship. Furthermore, exchanges between ESA and the manufacturers are close and interactive, which is more typical of a relational type BSR. Therefore, the relationship is a captive type, but with relational attributes (a captive-relational type BSR), which highlights the overlap between the GVC governance types.

The type of relationship between a commercial buyer and a manufacturer is also both captive and relational. However, the nature and structure of that relationship is still very different, since the commercial market is less concentrated. The differences between the sale of a commercial and institutional satellite are explored in section 6.4.2.

6.4.2 BSRs Governing the Sale of a Commercial Satellite

With commercial satellite projects, the procurement options available to operators are much less restrictive. For example, "*UK operators don't just buy from UK or European suppliers*" (GovFacilitator1b). Instead, they speak to "*four to five manufacturers*" and "*buy from whoever is most competitive*" (S.Operator1b; GovFacilitator1b). The consideration of a supplier's competitiveness is largely based on price. However, 'heritage' (i.e. the flight history of the satellite's components and experience of the manufacturers) is also a factor which operators consider (Chapter 7, Section 7.3), since it impacts on the insurance and licensing process. For example, if an operator chooses to put in place damage insurance to cover its satellite(s), then the cost of the insurance premium is influenced by the heritage of the satellite design (Chapter 5, Section 5.5.1). Similarly, part of the *space* licensing process involves the "inspection and testing" of the satellite technology (Chapter 5, Section 5.6) (Gov.UK, 2015). Consequently, the operators are again under pressure to contract an experienced manufacturer who would incorporate components with flight-history into the design of the satellite(s). Availability is also a factor, as one manufacturer "*might have such a large pipeline of builds on, that they can't deliver for three and a half years*", whereas another "*might be able to deliver in two years*" (S.Operator1b).

Meanwhile, fierce competition in the UK market results in limited commercial procurement opportunities for UK satellite manufacturers (Bensaou, 1999). For example:

> *"The world market for* [telecommunication] *satellites is about twenty to twenty-five* [contracts a year], *the European part of that is about ten to fifteen* [contracts]*... you*

> *then have a cat fight between* [the manufacturing primes]… *Last year we only won two contracts…* [L.Prime1] *won five" (M.Prime1a).*

This "*always means that there is a manufacturer out there that is hungry*" and that UK satellite manufacturers are transactionally dependent upon the UK and other global operators (M.Operator1b; S.Operator2c). This affords power to the operators over the manufacturers, encouraging the buyers to coordinate explicitly the supplier's activities through close and frequent interaction. The type of BSR outlined here is a captive-supplier. This contrasts to the captive-buyer exchanges identified in ESA contracts and highlights the significance of the end product (i.e. whether commercial or institutional) in altering BSRs at the same procurement stage.

A characteristic of captive-supplier BSRs is that the supplier often makes "transaction specific investments", particularly when it has a large order (Tangpong *et al*., 2008:573). By way of example:

> "*For the new satellite model, because we are making so many, we will specify the infrastructure [to the needs of a particular operator], for example the jigs and cranes for assembly*" (L.Prime1a).

Mudambi and Helper (1998:777) identify these buyer specific investments as "transaction-related hostages", as they increase switching costs and force the suppliers' commitment to the relationship. This causes the manufacturers to become even more dependent on the operators and suggests a captive type BSR.

The complexity of a commercial satellite transaction however, demands close interactions and two-way exchanges of knowledge (as discussed in section 6.5.1). Therefore, the nature and structure of a commercial satellite exchange can also be identified as a relational type

BSR. Furthermore, although they are not obligated to do so, transaction-specific investments by the manufacturers can encourage the operators to develop a long-term relationship with their suppliers in return. Prolonged exchanges provide an opportunity for the development of trust and decline in power asymmetries. In a trusting relationship, exchange partners perceive each other as capable enough to deliver their assigned tasks and motivated enough to benefit the relationship (Nyaga *et al*., 2010). Trust leads to greater “collaboration, adaptation, and commitment” (Corsten and Felde, 2004:450). For example, operators choose manufacturers they have worked with before and know they can trust. Trust is particularly valuable to commercial satellite operators because purchasing a satellite is such “a *massive investment”* and they “*need to de-risk the programme as much as possible*” (S.Operator2b). As a consequence, even though the manufacturer may have been transactionally dependent on the operator, as “*the incumbent”* it has an advantage over its competitors for future procurement (L.Prime1c). This empowers the manufacturers, leading to a more even distribution of power.

This redistribution of power means that the sale of a satellite, which begins as a captive type BSR with relational attributes (i.e. close interactions and knowledge sharing), can develop over time into a relational BSR. This is more likely to occur with satellite projects compared to other industries because such projects can last for such a long period of time (Figure 6.2). It is not specific to commercial contracts, as the sale of institutional satellites can also result in a long-term partnership, which continues after the initial purchase has been made.

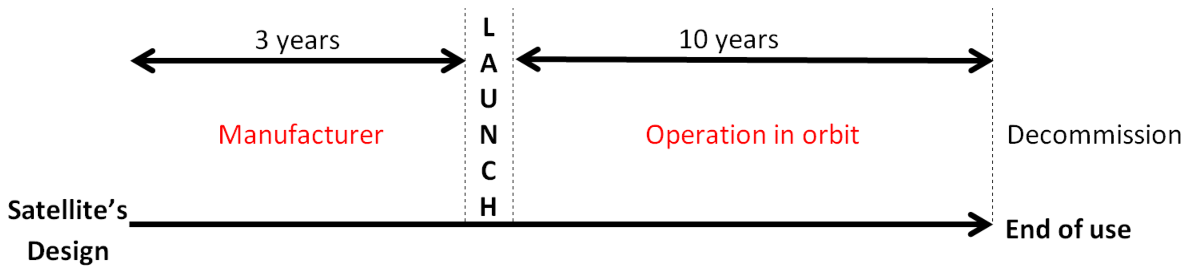


Figure 6.2: The timeline of a satellite.

Note: Depending on the terms of the contract, the manufacturer may have a relationship with the buyer up until the end of the satellite's use.

Source: Author.

This blurring of captive and relational type BSRs highlights how relational partnerships can be founded upon one-sided dependency. This is a significant contribution to the literature as it contradicts other "relational content-based typologies" that have suggested that "power-dependence becomes irrelevant in a highly relational BSR" (Tangpong *et al*., 2008:575). It also demonstrates how "power is fluid" and its distribution can change over time (Tokatli, 2007). Furthermore, it is evidence of how BSRs are not fixed, but can shift in nature over time (i.e. a BSR can develop and change from being one type of BSR to another type). Thus, time is a variable that impacts BSRs, something which Gereffi *et al.* (2005) did not identify in the GVC governance literature.

In a relational type BSR, power asymmetries are low because the buyer and supplier create value that neither of them could independently achieve (Nyaga *et al*., 2010). This is a result of the joint operations and close collaboration which typifies a long-term, relational partnership. Knowledge exchanges are also "more frequent and richer in content" than in a captive type BSR (Corsten and Felde, 2004:449). Because of the long-term nature of a relational type BSR, exchanges occur before the design and manufacture of the satellite even begins, as the buyer and supplier discuss future projects in advance of new contracts. The strong collaboration between the manufacturer and buyer means that both typically hold a portion of the satellite's IP. The manufacturer has to "*declare background IP at the beginning of the project*", whilst anything it does not declare is "*foreground IP*" that "*will be paid for by the customer and is theirs to keep*" (L.Prime2a). Therefore, manufacturers have to seek permission to use a final satellite design "*under licence*" from the initial client; they cannot freely sell it to another customer (L.Prime2a; S.Operator1b). Similarly, "*it's a difficult argument for any operator to make that the IP is exclusively their property*" because of background IP (S.Operator2c). This is relevant to even power distribution, as power is proportional to the firms' control of key resources, including intellectual and industrial property patents (Dicken *et al*, 2001; Coe *et al*, 2008; Martin-de-Castro, 2010). Design patents are particularly valuable in the *space* sector because as satellites are "high-performance products with high intellectual value", the majority of their costs are in the design (Rossetti and Choi, 2005:47).

As dependency and power are not completely one-sided, a captive type BSR does not apply to the sale of a satellite. Nevertheless, the foundations of the sale of a commercial satellite are still with the limited procurement opportunities for the manufacturers and their transactional dependency on the operators. A greater proportion of the power accordingly remains with the operator. This is evident with the division of IP, as the manufacturer only has a right to its background designs, irrespective of whether the innovations in the 'foreground IP' are driven by them. Additionally, even where trust develops, there can be no guarantee that the operators will choose the same manufacturer for future projects, especially when it is in their interest to avoid the development of a manufacturing monopoly (Rossetti and Choi, 2005). For example, one operator described a situation where it found it necessary to incentivise a US manufacturer back into the market:

> "*Boeing for example dropped out of the manufacturing side and only manufactured for the military side, so the commercial operators encouraged and incentivised Boeing to get back into the market because it offers competition. Because if there are only one or two manufacturers then the price will be higher, the costs will be greater*" (S.Operator3c).

An example of an incentive would be a guarantee of a contract for a new satellite or constellation, setting aside any close relationships with other manufacturers. Similarly, another research participant highlighted the dangers of collaborating too closely with a single supplier, as it can lead to technological lock-in and high costs:

> "*…they are almost too close. So they are designing systems for those customers and because they are so focussed on those* [customers]*, they have allowed people like Planet Labs, One Web*[10] *to come in and provide a lower cost service, which if they are not careful could do them some damage in a few years' time*" (GovFacilitator2c).

Therefore, whilst there is not a one-sided power relationship as with a captive type BSR, in a commercial project the manufacturer is more dependent on more powerful operators. Similarly, in an institutional satellite project, the buyer is still limited to a select group of suppliers because of procurement rules.

Consequently, the sale of a satellite in the UK *space* sector cannot be categorised as a single type of BSR, since the nature and structure of the interactions between the

[10] Planet labs and One Web are American low-cost satellite operators. Their products are real time satellite imaging and space-based internet services. They have ambitions to launch constellations of hundreds of satellites. This will be a break with heritage (Chapter 7).

manufacturers and operators have the characteristics of both relational and captive governance forms (which change over time). They are captive-relational type BSRs. This highlights the challenge of making a typology work when applying it to a new industry and the need for flexibility in the operationalisation of types, since they can overlap.

6.4.3 Section Overview

This section has identified that captive-relational type BSRs govern the sale of a satellite in the context of the UK *space* sector. Suppliers are chosen on the basis of *juste retour* (if an ESA satellite), price, heritage and availability. The key findings are summarised in Table 6.2, which outlines the nature and structure of the BSRs. The table separates the BSR characteristics into five categories (or columns). First, features of BSR types from the GVC governance typology are outlined (Gereffi *et al*., 2005). The typology was slightly adjusted to address the criticisms outlined in Chapter 2 (Section 2.4.2). For instance, it distinguishes between captive-buyers (in ESA projects) and captive-suppliers (in commercial projects). This contradicts the narrow focus in the GVC governance literature on how buyers coordinate their suppliers in a “top-down process” (Lee and Gereffi, 2015:321). Additionally, the ‘degree of coordination’ and ‘power asymmetry’ of BSRs were prioritised as variables, above ability to ‘codify information and supplier capability’ which are more subjective (Gibbon *et al.,* 2008:8). This adjustment affected the operationalisation of the BSR types and in turn highlighted how relational and captive type BSRs can overlap, since an exchange of a satellite can have characteristics of both. The impact of external governance factors on BSRs were also considered (Gibbon *et al.,* 2008; Rainnie *et al.,* 2011). For example, obtaining an orbital slot (if a geostationary satellite), frequency spectrum and damage insurance are governance processes which impact on procurement decisions (i.e. which manufacturer an operator should choose).

However, there are other important aspects of the BSRs, which are not part of the GVC governance typology but are relevant to this analysis on the UK *space* sector. These make up the other four categories (or columns) in Table 6.2. First, there are different groups of buyers (i.e. institutional and commercial) who interact differently with the same supplier. Therefore, depending on which buyer is involved, the nature and structure of the BSRs will vary. This is a valuable contribution, since Gereffi *et al*. (2005) focussed on the type of relationship between a single purchaser and single supplier, whereas it is not that simple as, in reality, a number of different firms/products are involved. Second, the technology involved impacts on the BSRs. This industry specific feature has previously been ignored in the GVC governance literature because, apart from electronics, the typology was based on low tech industries (bicycle, apparel, horticultural) (Gereffi *et al*., 2005). Third, while time is a variable that impacts BSRs, it is overlooked by Gereffi *et al* (2005). For example, a longer-term relationship between a manufacturer and an operator can facilitate the development of trust and encourage interdependency. Additionally, geography is a critical part of the nature and structure of any BSR. The additional categories or columns in Table 6.2 demonstrate that while the GVC governance typology is a useful conceptual framework, there are additional features of BSRs which require consideration.

Table 6.2: A Summary of the Characteristics of BSRs Governing the Sale of Satellites.

BSRs	GVC Typology	Buyers	Technology	Time	Geography
Sale of an institutional Satellite	- Captive-buyer: There is a concentrated market of "few established players", with stable demand and limited market growth (Bensaou, 1999:38). Therefore, the buyers are transactionally dependent on the suppliers. - Relational: The complexity of the product requires a close, two-way dialogue, as opposed to a "unidirectional flow of information and control" (Gereffi *et al.*, 2005:87).	- ESA procurement rules limiting potential suppliers. - ESA missions do not always involve the most innovative technologies and suppliers, but instead those which politically fit with their procurement criteria (Chapter 5).	- ESA satellites are "Europe's first" or "next-generation" technology demonstrators, which makes the product more innovative and the transactions more complex (ESA, 2016). - Ideas are shared between the two exchange parties during all stages of design. The intense collaboration between the manufacturer and buyer means that both will typically hold a portion of the satellite's IP.	- Longer term exchanges provide opportunity for trust to develop and power asymmetries to decrease. Trust leads to greater "collaboration, adaptation, and commitment" (Corsten and Felde, 2004:450).	- The *juste retour* means that both the manufacturer and operator involved in the BSR are based in the same country. The buyer's choice of supplier is also limited to those based in ESA member states. - Temporary proximity between the buyer and supplier is important. This is facilitated by shared site visits.
Sale of a commercial satellite	- Captive-supplier: The suppliers have limited procurement opportunities and high switching costs because of buyer specific investment. Therefore, suppliers are transactionally dependent on the buyers. - Relational: There is a close, two-way dialogue, as opposed to a "unidirectional flow of information and control" (Gereffi *et al.*, 2005:87).	- Institutional procurement rules do not apply, so there is "high growth" and "fierce competition" in the market (Bensaou, 1999:38). - An operator's consideration of a manufacturer's competitiveness is based on price, heritage and availability.	- Ideas and IP are shared, as with the sale of an institutional satellite. - Trust is particularly valuable to commercial satellite operators because purchasing a satellite is such "*a massive investment*" and they "*need to de-risk the programme as much as possible*" (S.Operator2b).	- Trust develops and power asymmetries decrease over time. This is more likely with satellite projects, compared to other industries, because they can last for such a long period of time.	- UK operators "don't just buy from UK or European suppliers" (GovFacilitator1b). - Temporary proximity between the buyer and supplier is important. This is facilitated by shared site visits.

Source: Author.

Section 6.5 explores the BSRs involved in the sale of satellite-enabled applications and make comparisons to the captive-relational type BSRs identified in this section. Although separate procurement moments, the sale of a satellite is a core necessary component of the sale of a satellite-enabled application. Additionally, the capability of the satellite determines the technological possibilities of the application. Consequently, later in the chapter (section 6.6), the analysis on both BSRs is brought together.

6.5 Sale of Satellite-enabled Applications

Forms of industrial governance often vary between different stages of a value chain (Gereffi *et al*., 2005). Therefore, the BSR type can be expected to vary when linking different production projects in a satellite mission. This section highlights these differences by focussing on the sale of satellite-enabled applications. This, in addition to Section 6.4 on the sale of satellites, will provide a more complete understanding of the overall governance of UK satellite missions.

Similar to the sale of satellites, there is not a single BSR type governing the sale of UK satellite-enabled applications. Instead, the BSR types vary according to three factors: buyer, contract and satellite function. First, there are four groups of potential buyers for the sale of a satellite operator's product (meaning bandwidth, transponder capacity or EO data), and the BSR type varies between these different groups of buyers. The four groups of potential buyers are: (i) end-users; (ii) service providers; (iii) market resellers; and (iv) other operators who have insufficient capacity of their own (Figure 6.3). Service providers buy bandwidth or transponder capacity and include satellite television broadcasters. Resellers are otherwise known as 'consolidators' in the marketing literature and act as an intermediary between multiple suppliers and buyers (Fairchild, 2003; Caiazza *et al*., 2016).

They purchase transponder capacity, bandwidth or data from satellite operators and service providers, package them into a single product and sell that product on to other service providers, resellers or end-users (Palmer and Quinn, 2003; Barrett, 1998).

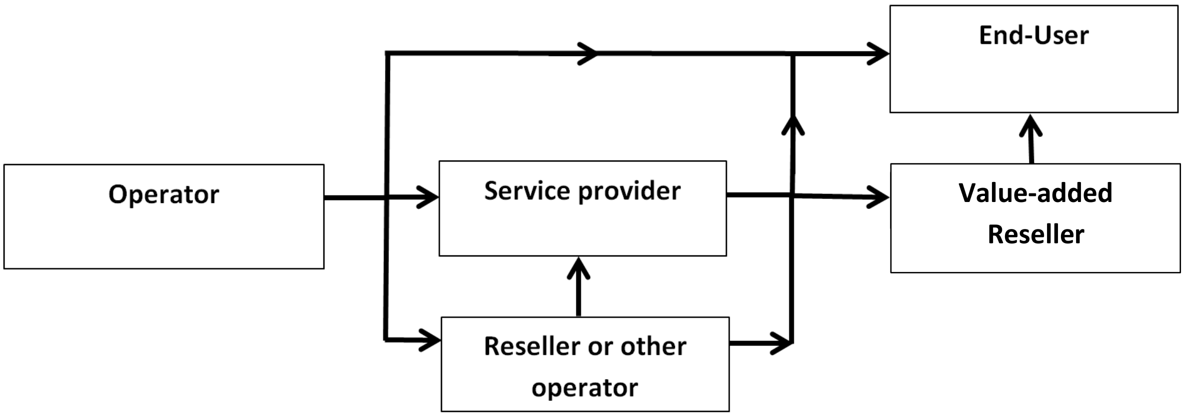


Figure 6.3: Transaction routes available to a UK satellite operator selling its satellite-enabled application.

Source: Author.

Secondly, operators offer a range of service level agreements and contract lengths, which also alter the nature of BSRs. Finally, telecommunications, Earth observation and navigation satellites all offer different applications, each of which vary in complexity and associated transactions. Consequently, this section separates the analysis of BSR between telecommunications and Earth observation applications. Satellite navigation is a public service and Galileo (Europe's Global Satellite Navigation System) therefore is organised through a public procurement project, which was discussed in Chapter 5 (Section 5.4.2).

6.5.1 Telecommunications Satellites

Telecommunication satellites provide a mix of applications including television broadcasting and internet broadband. These applications are delivered direct to home (DTH) via small dish antennae and satellite receivers or to a very small aperture terminal

(VSAT), otherwise known as a two-way satellite ground station. DTH is commonly used for television broadcasting, whereas VSATs are used to deliver satellite broadband to locations where fibre optics are not possible, for instance in remote areas and on-the-move transport infrastructure. For television broadcasting, UK operators sell bandwidth capacity to other operators, resellers and DTH providers (Chapter 4, Section 4.2.4). Those operators, resellers and DTH providers then directly or indirectly (via further resellers) deliver the service to end-users. Meanwhile, internet broadband is provided via VSATs and the operators either deliver the application directly to users (for example, to a ship), or again pass the bandwidth capacity onto a reseller, another operator or service providers. The type of buyer and whether an application is delivered DTH or via VSAT determines the BSR type which governs its sale.

DTH Television Broadcasting

There are a "*limited number of satellite operators"* who can supply the requisite bandwidth capacity for television broadcasting (L.DTHApplications1). This is due to the limited number of operators who have access to geostationary orbital slots. DTH signals rely on satellites in geostationary positions because they are able to maintain a fixed position relative to the Earth and, most importantly, are a "stable target" for a small dish antenna (Warf, 2006:386). There are only 1,800 available geostationary slots (Chapter 4, Section 4.3), the majority of which have already been allocated to existing operators through a 'posterior' (first-come, first-served) allocation system (Chapter 5, Section 5.3). Consequently, there is a first-mover advantage (FMA) with orbital slot and frequency spectrum (Tokatli, 2007). This FMA poses significant barriers to entry for new operators, and thus the market remains concentrated with a small number of established players monopolising the market: "*we've got it, nobody is having it. It's very limited, hugely* *sought after*" (L.Operator1a). Consequently, operators have strong bargaining power over their buyers; the latter becoming transactionally dependent on the former as a result of there being few other suppliers in the market. This is characteristic of a captive-buyer type BSR.

In addition to market constraints, service providers are dependent on the operators because of sunk costs and associated path dependency. Sunk costs are those costs which are "committed to a particular use, and therefore are not recoverable in case of exit'" (Clark and Wrigley, 1995:205). Therefore, they lock buyers into captive type BSRs. By way of example:

> "*Once* [the buyer has] *decided to go with a particular operator whoever it is*, [the operator] *puts up the infrastructure, the routers and the satellite and equipment in and the back-up calls and all of their network operations up, it's very expensive to go and do all that again*" (M.Operator2).

Therefore, the largest UK DTH provider is dependent upon a single operator which owns the rights to the slot that the provider's dishes are pointing to. The provider is "*locked in"* to that BSR (L.Prime1b). The UK DTH provider could follow the recent step taken by a Scandinavian satellite broadcaster and send an engineer out to alter the angle of all of its customers' small dish antennae: "*they turned a million and half satellite dishes from* [pointing at] *one orbital position to another*" (L.DTHApplications2). However, this would not be "*an economically sustainable thing"* for the UK DTH provider to do, as it would have a less manageable number of "*10 million dishes to move*" (L.DTHApplications2). Therefore, the DTH provider remains dependent on the supplier who owns the relevant slot. This is a further example of path dependency and can be detrimental to the competitiveness of the firm because it locks it into technologies and processes that may be inferior to those of its competitors (Martin and Sunley, 2006; Isaksen, 2014; Sydow and Koch, 2009; Turco and Maggioni, 2014). The monopoly position which a few commercial operators find themselves in also keeps costs high.

Over time, the relationship between the operators and service providers can develop into a more relational type BSR with two-way interdependency. This development is similar to the findings on the sale of the satellites and was found to have happened with the UK DTH provider and its operator. The evidence demonstrating this interdependency is that the operator now relies on its buyers' custom (i.e. security of future contracts) for making future investments:

> "*I am damn sure that they wouldn't have placed the orders for the new satellite without there having been given a degree of comfort from us that we would give them business*" (L.DTHApplications2).

While the operator could offer the bandwidth capacity to another service provider if necessary, the scale of the existing BSR contract would be difficult to be matched by a smaller provider (its current buyer is the largest in the UK) and so change could put the operator in a vulnerable position. Maintaining a relationship with its existing customer also helps the operator to avoid switching and trading costs (e.g. ordering, delivery, monitoring, and contract enforcement costs) (Richardson, 1993).

Furthermore, although a satellite is capable of "*serving multiple regions*", its antennae are often "*inflexible*" and "*shaped in a certain way, which can only focus on a concentrated area*" (L.Prime1a). Therefore the satellite signals "serve only a portion of the satellite's overall footprint" (GAO, 2011) and this locks them into a particular target market (for example, the UK) (Chapter 4, Section 4.2.3). This means that the geography of the BSRs governing the sale of DTH bandwidth is restricted to set regions, since the operators are locked into customers located in the Earth footprint of their orbital slot. There are satellites now in orbit with steerable beams that can change the direction of their antennae, and therefore their target market, if required. However, understandably given their complexity, steerable beams are more expensive than fixed beams and are also considerably larger, which impacts on the satellite weight and therefore the launch cost (Symonds, 2009). Consequently, the new technology is not yet widespread and in the case of a geostationary satellite, then its footprint is still limited by its orbital slot. Therefore, it is often in an operator's interest to maintain their relationship with the service provider. They achieve this by developing a close-relationship, with a two-way exchange of ideas:

> *"So every three or four months* [an operator's] *technical team come and tell us what they are up to with each new satellite, new plans, news ideas, seek our input if they think it is something relevant to us"* (L.DTHApplications2).

The outcome is more of a relational type BSR, where the service provider has an ongoing discussion with the operator about its needs. This again highlights the overlap between the GVC governance types.

There are other types of relationships involved in the sale of bandwidth capacity in the UK DTH market. Alongside the long-term leases typically for the larger service providers, there are also occasional-use contracts, whereby the customer (such as a news broadcaster) is not committed to a 'recurring service' but is instead engaged on "an as-needed basis" (Gershon, 2009:186). Furthermore, the operators do not have sufficient resources or "*enough people*" to establish relational BSRs with all of their customers, particularly smaller broadcasters (S.Operator3c). Instead, they have modular type BSRs with resellers who "*act as a broker to the smaller customers*" (S.Operator3c). In modular BSRs, the complexity of the transaction remains high, with non-standardised products. However, the structure of the relationship is more 'fluid' than relational and captive type BSRs, since both the suppliers and buyers work with multiple partners. The contrast between the modular and relational type BSR highlights the impact that different buyers can have on the sale of a satellite-enabled application. Similarly, resellers and other operators buying bandwidth capacity are not locked-in to relationships with particular operators (as is the case with DTH providers), as their customers, not them, will accrue path-dependent sunk costs.

VSAT Positioning and Broadband Services

The sale of a VSAT service is "*less sticky*" than a DTH application because VSATs are not restricted to a fixed position (S.Operator3c). Nevertheless, they do still rely on geostationary satellites and therefore a select group of operators. However, the flexibility of VSATs means that the buyer is not locked into a particular supplier. For example, for a VSAT network for an oil and gas company:

> "... [the buyer] *might have 40 antennae at different locations, but you can easily manage to repoint those to another satellite when the contract is up for renewal*" (S.Operator3c).

This means that relationships are "*more short-term*" and there is not a captive-buyer BSR in place (S.Operator3c). Instead, similar to the operators' relationship with DTH resellers, the nature of the exchange with VSAT customers is modular. This again highlights the variety of products in the *space* sector and how they influence BSR types.

The most common VSAT service is satellite broadband, which is necessary in remote locations where there is no access to "*fibre optic broadband*" (M.Prime1a). Since most of the UK has fibre access, the majority of these 'remote locations' are outside the UK. For example, "*Africa doesn't even have telephone lines in some places, they are totally reliant on satellite data links*" (M.Prime1a). Therefore, developing countries are a significant target market for UK VSAT operators. Another key target market is on-the-move transport infrastructure, such as ships and planes. Consequently, VSAT services are primarily an exporting business. If a 'managed service' (i.e. where the operator is responsible for supplying the internet connection to the end-user), the BSRs governing the sale of the application are geographically dispersed. However, these BSRs are not as long as the "*big broadcast contracts*" because of the flexibility of VSATs; typically, they last "*three to five years*" (S.Operator2c). Depending on the contract, there are different service level agreements which usually correspond to price. For example, non-pre-emptible transponders or leases are cheaper than pre-emptible transponders and are not protected in the event of failure. They are for "*non-essential communications*", as they are often spare transponders which if needed by another more important, larger customer, then communications will be "*switched off*" for other customers (L.Insurer1). Other more expensive contracts do not present this risk and even "*require the operator to use a replacement satellite*" in the event of failure (L.Insurer1). Depending on which service-level agreements are in place, the nature of the relationships will change. For example, a more expensive contract is likely to involve closer interactions, despite the distance between the operator and buyer.

However, in the majority of cases it is resellers who deliver the VSAT service to the end-user (business-to-consumer or B2C). By way of illustrating, the largest UK operator is "*essentially a wholesaler*" and has modular BSRs with a group of resellers (L.Operator1a). These resellers are "*retail businesses*", which "*buy space segment and package it up as* *their own service*" (L.Operator1b; S.Operator3a). The operators do have "*some direct activity*" but they are always careful not to encroach on the markets of their 'retail' customers (L.Operator1a). The provision of VSAT applications to the end-user is also a "*very different business*" to satellite operation. The operator finds that resellers are more proficient at this because they have "*more people*" and are "*more localised*" (L.Operator1b). This highlights the importance of proximity between a VSAT supplier and end-users and how, if this is not achievable for a satellite operator, they rely on a network of resellers who are located closer to the end-users.

The BSR between VSAT operators and resellers, and not end-users, is significant because it means that the operators are not responsible for the different service-level agreements described above (it is a business-to-business relationship instead of business-to-consumer):

> "*We* [the operator] *sell bandwidth, we don't sell the service* [to the end-user]. *So we are not going to actually say we guarantee you service x*" (M.Operator1a).

This results in less frequent exchanges with the customer, which contrasts to the more relational exchange between a satellite and DTH service. The BSR governing the sale of Earth observation data is even further from a form of relational governance and is more characteristic of a market BSR. This difference between telecommunication and Earth observation applications will now be explored.

6.5.2 Earth Observation Satellites

Earth observation (EO) satellites monitor the planet's environment and weather systems. They contribute 3% to the UK *space* industry's turnover which, compared to telecommunications, is a small proportion (for example, 63% is broadcasting alone) (London Economics, 2015). Consequently, the number of BSRs governing the sale of

Earth observation data is considerably less than telecommunications services. Therefore, there is a shorter analysis in this section, compared to the previous one.

There are three groups of buyers that an operator may target for the sale of EO data: (i) end-users; (ii) value-added service providers; and (iii) resellers. The most common of these buyers are value added service providers, who add value to raw observation data through "*management and analytics*" (GovPolicy3d; S.SystemsManufacturer1a) (Chapter 4, Section 4.2.4). The value added service providers differ from data resellers because they transform the data into a usable information service and deliver a "functional result", rather than a "pre-determined product" (Bryson, 2009:20).

The EO satellites which monitor UK weather systems are limited to geostationary slots, since they require a fixed position to allow continuous observation. Satellites monitoring the planet's environment are not restricted in the same way, provided they are not required to constantly observe an area. This is important as it means that buyers of EO data (other than weather) are not restricted to the same geostationary slots like buyers in the telecommunications market. This creates a less concentrated market, since there are lower barriers to entry and greater opportunities for new players.

Similar to telecommunications, the nature of the BSRs governing the sale of EO applications changes between different buyers. For example, if there is a direct relationship with end-users, then the BSR type will be modular. This relationship has a more fluid structure because the suppliers and buyers have opportunities to work with multiple partners, whereby there is low dependency on both sides (Gereffi *et al.*, 2005). However, the complexity of the transaction remains high, with products that are not standardised. For example, one operator "*might have agreements to provide regular down links to a* *customer's site*", whereas another may be contracted "*to provide imagery over certain geographical areas within a certain time*" (L.Prime2c). The bespoke nature of the service delivery is what prevents the BSR from being a market type.

Direct relationships with end-users are uncommon, since EO operators tend to sell predominantly to resellers and value-added service providers. Therefore, the market is more "*commoditised*", with the buyers "*comfortable with going to lots of different sources*" and not being locked into a single supplier (S.DataApplications1). By way of example:

> "*We* [the value-added service providers] *are not tied to any one company, we have a series of agreements with a few but they are not exclusive, some are public sector, some commercial. We have one framed contract with a European reseller, but we do that to give them the confidence of a volume of orders, so they can give us a discount on the data, but I can go to another player if I want to*" (Mi.DataApplications3).

This is defined as an 'exit relationship', characterised by "low commitment", "a low level of information exchange" and a high probability that the buyer will switch suppliers (Mudambi and Helper, 1998:778). The products are also standardised, whereby the same data is available to all customers (telecommunications services often require buyer specific transponders). The low commitment and standardised nature of the exchange is characteristic of a market type BSR (Gerrefi *et al*., 2005).

The EO data is sold on the operator's website or via other resource platforms that resemble the "*iTunes of satellite imagery*" (S.DataApplications1). Generic 'iTunes' type websites "*enable users to look for and then select satellite data for their needs*" (Mi.DataApplications1a). The "*local market isn't really there*" for UK EO operators because "*it is a small country*", in which the "*use of aerial imagery* [from planes]" has made it a "*data rich environment"* (S.DataApplications1). Therefore, like VSAT services, EO data provision is predominantly an export business to developing countries "*with considerable data needs*" (L.Prime2c). Consequently, buyers are typically located large distances away from the UK operators. The market type nature of the exchange does not demand face-to-face interactions and so, the distance from their buyers is not difficult for the operators to manage. Instead, the EO data can be purchased online from "*pretty much anywhere*", leading to a disconnect between the satellite infrastructure and end-users (Mi.DataApplications1a; Section 4.2.4). For example:

> "…*some of our* [value-added service provider] *customers couldn't care less about the satellite part and just want to see a satellite image as quickly and cheaply as possible*" (S.DataApplications1).

This is significant, as it results in limited feedback between the operator and end-user: "*the downstream sector will be talking to the resellers and not the operators*" (GovFacilitator2b). This is potentially detrimental as it limits the available information to the operator for the purpose of providing feedback to the manufacturer: "*we do speak to the operators, but not the actual end-users, no*" (L.Prime2a).

6.5.3 Section Overview

This section has identified the types of BSRs governing the sale of satellite-enabled applications in the UK *space* sector which are typically: (i) captive-relational (if a DTH application); modular (if a VSAT application); and market (if an EO application). Factors impacting the choice of suppliers include: footprint, sunk costs, availability and price. The key findings of this section are summarised in Table 6.3. This table differentiates between various BSRs with different buyers (i.e. end-user, service providers, market resellers and other operators); contracts (i.e. varying lengths and service level agreements); and satellite functions (i.e. telecommunications and Earth observation).

The above three variables create different BSRs and result in there being no single BSR type governing the sale of UK satellite-enabled applications. Consistent with Table 6.2, Table 6.3 separates the BSR characteristics into five categories (or columns). The first category involves features of BSR types from the GVC governance typology (Gereffi *et al*., 2005). The remaining categories are important aspects of the BSRs, which are not part of the GVC governance typology but are relevant to this analysis on the UK *space* sector, namely: (i) buyers and contracts; (ii) technology; (iii) time; and (iv) geography. The additional categories in Table 6.3 reinforce the point that while the GVC governance typology is a useful conceptual framework, there are additional features of BSRs which require consideration.

Table 6.3: A Summary of the Characteristics of BSRs Governing the Sale of Satellite-Enabled Applications.

BSRs	GVC Typology	Buyers and Contracts	Technology	Time	Geography
Sale of DTH application	- Captive-buyer: There are "few established" geostationary operators, with stable demand and limited market growth (Bensaou, 1999:38). - Relational: In longer-term relationships there is a close, two-way dialogue, as opposed to a "unidirectional flow of information and control" (Gereffi *et al.*, 2005:87).	- With long-term leases, larger service providers become transactionally dependent on the operators.	- DTH operators rely on geostationary slots, which allow their satellites to maintain a fixed position relative to the Earth's rotation and are a "stable target" for a small dish antenna (Warf, 2006:386; Copiz, 2001). - Buyers become locked-in to slot specific infrastructure (dishes pointing in a certain direction).	- Over time, two-way interdependency develops between the operators and service providers, as the operator relies on the security of future contracts.	- The geography of the BSRs governing the sale of DTH bandwidth is restricted to set regions, since the operators are locked into customers located in the Earth footprint of their orbital slot.
	- Modular: Has a more fluid structure because the suppliers and buyers have opportunities to work with multiple partners; there is low dependency on both sides (Gereffi *et al.*, 2005).	- There are also occasional use contracts whereby the buyer (such as a news broadcaster) is not committed to a 'recurring service' but "an as-needed basis" (Gershon, 2009:186). - The BSR between resellers and other operators also has a more fluid structure.			

Sale of VSAT application	- Modular: The complexity of the transaction is high (Gereffi *et al*., 2005). - Modular: The structure is very 'fluid' with both the suppliers and buyers working with multiple partners (Gereffi *et al*., 2005). - Modular: There are low levels of explicit coordination and power asymmetries (Gereffi *et al*., 2005).	- Depending on the nature of the contract there are different service level agreements, which usually correspond to price.	- The use of a very small aperture terminal (VSAT) provides greater flexibility than when relying on small dish antennae and satellite receivers (DTH). This means that the buyer is not locked into a particular supplier.	- The flexibility of VSATs means that the buyer is not locked into a particular supplier. This means that relationships are shorter-term.	- Proximity between the supplier and end-users is important and achieved via a network of resellers, who are located closer to the end-users. - VSAT services are primarily an export business. If a "managed service", the BSR governing the sale of the application are geographically dispersed.
Sale of EO application	- Power asymmetries are low, as both the buyers and suppliers work with multiple partners (Gereffi *et al*., 2005). - Market: There is a high probability of supplier switching (Gereffi *et al*., 2005).	- Product specifications are typically standardised (for resellers and value-added service providers) unless selling directly to the end-user.	- The EO data is sold on the operator's website or via other resource platforms that resemble the "itunes of satellite imagery" (S.DataApplications1).		- Data can be accessed "*pretty much anywhere*" and that the value-added service providers are not restricted to certain locations, unlike *space* manufacturers and operators (Mi.DataApplications1a).

Source: Author.

6.6 Interactions between Different BSRs in the UK *Space* Sector

This section focusses on the interactions between different BSRs by linking the proceeding analysis concerning the sale of satellites with the analysis relating to satellite-enabled applications. This provides a more complete overview of the nature and structure of the relationships governing a satellite mission. The analysis considers each of the variables that determine the operationalisation of BSR types, as identified by Gereffi *et al*. (2005). However, the ‘ability to codify information’ and ‘supplier capability’ have been criticised as being subjective variables in the GVC typology (Gibbon *et al.,* 2008:8). This subjectivity is a result of the lack of a clear definition of what constitutes as a necessary ability and as a sufficient supplier (Gereffi *et al.,* 2005). Therefore, the analysis places greater importance on other variables in the GVC typology (i.e. degree of explicit coordination and power asymmetry). The findings highlight the different origins and timings in respect of when power is important within the BSRs. Section 6.6.1 focusses specifically on power distribution within ESA projects.

6.6.1 Power Distribution in Institutional Satellite Projects

With regard to satellite projects that are funded by ESA, there is a fairly even power distribution between ESA and UK satellite manufacturers as both parties are empowered in different ways (see Figure 6.4). For instance, as the funder of the project and the entity enforcing the procurement rules (*juste retour*) (Chapter 5, Section 5.4.2), ESA has a degree of power over the manufacturers. Additionally, ESA satellites are often highly bespoke technology demonstrators and thus the transaction is complex and requires a degree of explicit coordination by the buyer over the manufacturer. However, only a select group of manufacturers meet ESA’s procurement criteria (*juste retour*), thus as a dominant player in an established market, the manufacturer also holds some power in the relationship.

Additionally, the complexity of the transaction is so high that it requires significant collaboration between the manufacturer and ESA, thereby creating a more relational type exchange.

ESA works alongside operators to ensure that the satellite-enabled applications are delivered (either directly or indirectly) to end-users. Since ESA satellites are predominantly "*technology driven*", the "*end-users have little say about the service that is delivered*" (GovPolicy2c). Consequently, they have limited power in institutional satellite projects, although they do benefit from them. In contrast, commercial telecommunications projects are more service driven and the end-users have a greater influence. These commercial projects will now be explored.

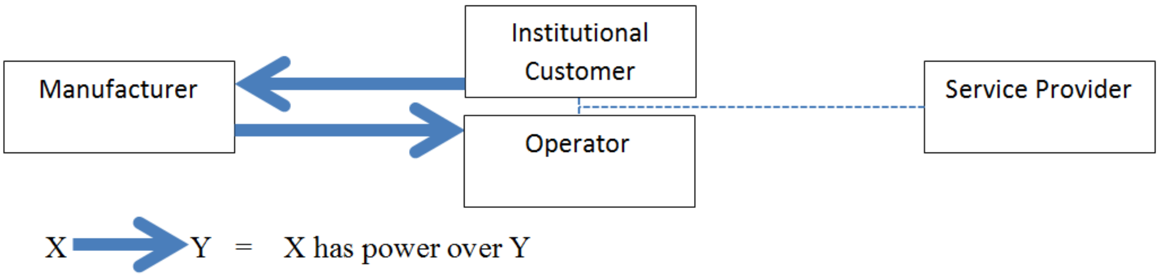


Figure 6.4: Demonstrating a fairly even power distribution in institutional satellite projects.

Source: Author.

6.6.2 Power Distribution in Commercial Telecommunications Projects

In commercial telecommunications projects, the most powerful agent is the satellite operator as both the manufacturer (i.e. the captive-supplier) and service provider (i.e. the captive-buyer) are transactionally dependent upon them. Manufacturers are dependent on the operators because they have limited procurement opportunities in the concentrated supplier market, whilst the service providers rely on the operators' geostationary slots (Figure 6.5).

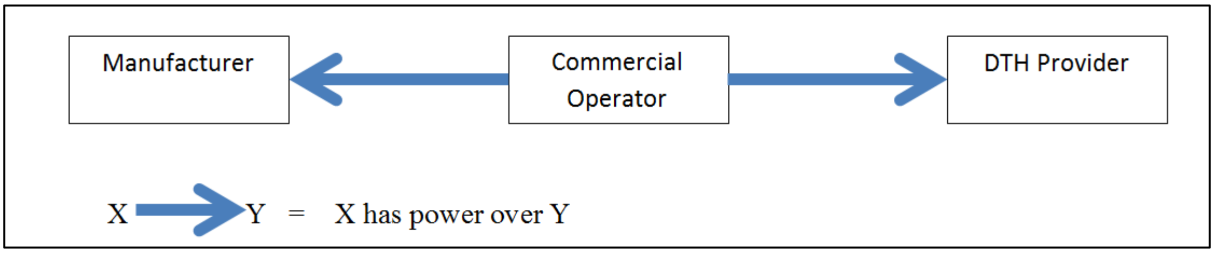


Figure 6.5: Demonstrating high power asymmetry in a commercial telecommunications satellite project.

Source: Author.

Nevertheless, the high complexity of the sale of a satellite necessitates relational type interactions. In addition, over time, two-way interdependency develops, between the operators and DTH providers, as the operator relies on the security of future contracts. Furthermore, since VSATs are more flexible than small dish antennae/satellite receivers, VSAT providers are not as locked-in to BSRs as DTH providers. Having said this, they are still restricted to geostationary operators.

6.6.3 Power Distribution in Commercial EO Projects

The EO satellite manufacturing market is less concentrated than the telecommunication market, since there are lower barriers to entry (i.e. there is no dependence on obtaining a geostationary slot) and thus greater opportunities for new players. As a result, the power asymmetries between the manufacturers and operators are lower than in telecommunications projects. In addition, the satellites are smaller and cheaper, thus while they remain complex and require some level of relational interactions, the intensity of those interactions (i.e. explicit coordination) is lower than in telecommunications projects. Meanwhile, EO applications are delivered in the format of imagery data, which customers (such as value-added service providers) can access in a standardised format through a market type BSR. The value-added service providers are not restricted to buying from geostationary operators, but rather, are free to switch between multiple operators and resellers with data from the appropriate footprint. This freedom results in value-added service providers being more powerful than DTH and VSAT providers in their respective BSRs (Figure 6.6).

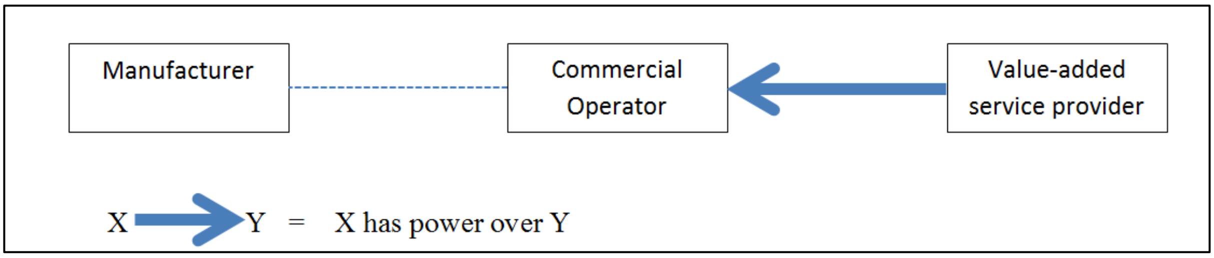


Figure 6.6: The applications provider holds the power in a commercial EO satellite project.

Source: Author.

6.6.4 Section Overview

This section has provided a more complete overview of the nature and structure of relationships governing linked satellite projects. This is a valuable contribution as one of the criticisms of the GVC governance typology has been its failure to distinguish between ‘coordination’ (between lead firms and suppliers at a particular segment of a value chain) and ‘overall governance’ (which accounts for various BSRs collectively) (Gibbon *et al*., 2009).

The analysis has also highlighted how, depending on the type of satellite project (i.e. institutional, commercial, telecommunications or EO), the most powerful actor(s) vary. However, in the UK *space* sector, commercial telecommunications constitute the majority of the market, for instance, 83% of the UK satellite industry's turnover in 2012/13 was from commercial telecommunications (London Economics, 2015). Therefore, in the UK *space* sector, commercial telecommunications operators are the most powerful actors due to the dependency of both manufacturers and service providers. From a policy perspective, this is a valuable contribution, since it is important to understand who the key players are and where to direct, or as the case may be, not direct funding support.

6.7. Conclusion

This chapter has explored the varying nature of BSRs at different phases of UK satellite missions. The result is a development of the existing applications of the GVC governance typology, which have focussed on one specific node in a value chain (Ponte *et al*., 2008). This is despite the literature having identified that there are varying relationships at different stages of production (Gereffi and Lee, 2012).

The analysis of BSRs in the UK *space* sector was divided between: (i) the sale of satellites; and (ii) the sale of satellite-enabled applications. The GVC governance typology provided a useful framework for conceptualising the character and structure of these relationships, with adjustments made to the typology to address any criticisms (Gereffi *et al*., 2005; Gibbon *et al*., 2008; Yang and Coe, 2009; Rainnie *et al*., 2011). These adjustments include: (i) focussing on more than a single procurement moment; (ii) distinguishing between captive-buyers and captive-suppliers; (iii) prioritising the degree of coordination and power asymmetry of BSRs above the ability to codify information and supplier capability; and (iv) considering external governance factors.

Table 6.4 summarises the differences between the procurement moments within a satellite mission by assigning each to the different types of BSRs. Changes to the five original GVC types have been made to reflect the research findings. For instance, the hierarchical type is omitted from Table 6.4 because it was found to be uncommon in the industry. Additionally, a distinction has been made between captive-buyers and captive-suppliers. This accounts for the fact that the buyer may not always be the dominant party.

Table 6.4: Identifying which of the GVC Governance Types are Applicable to Various Procurement Moments.

Sale of…	**Types of BSRs**				
	Market	**Modular**	**Relational**	**Captive-Buyer**	**Captive-Supplier**
Institutional Satellite			**X**	**X**	
Commercial Satellite			**X**		**X**
DTH Application			**X**	**X**	
VSAT Application		**X**		**X**	
EO Application	**X**	**X**			

Source: Author.

Table 6.4 illustrates that characteristics of different BSR types may be present in the same procurement moment. With the sale of applications, this is partly explained by the impact of varying buyers and contracts on the BSRs. However, there is also an overlap between the relational and captive type BSRs. This blurring of captive and relational type BSRs highlights how relational partnerships can be founded upon one-sided dependency. This is a significant contribution to the literature, as it contradicts other "relational content-based typologies" that have suggested "power-dependence becomes irrelevant in a highly relational BSR" (Tangpong *et al*., 2008:575). It also demonstrates how "power is fluid" and its distribution can change over time (Tokatli, 2007). Consequently, BSRs are not fixed, but influenced by the passing of time. There were also other factors (namely buyers and contracts, technology and geography) which were found to impact on the BSRs. These additional factors demonstrate that while the GVC governance typology is a useful conceptual framework, there are additional features of BSRs which require consideration.

Understanding organisation of production is an important part of exploring firm-level competitiveness, since organisation and competitiveness are intrinsically linked. For instance, a firm's decision about whether or not to vertically integrate production tasks is part of its competitive strategy. Similarly, the character of a firm's relationship with its buyers and suppliers is an external factor which impacts on its competitiveness. Furthermore, governance is an external factor which influences the "nature of competition" of UK satellite firms (Nachum, 1998:465; James *et al.*, 2013; Borggren *et al.*, 2016; Turco and Maggioni, 2014). To conclude, findings from this and the previous chapter contribute to understanding the competitiveness of UK satellite companies, which is explored in the next chapter.

CHAPTER 7

SOURCES OF COMPETITIVESS FOR UK SATELLITE FIRMS

7.1 Introduction

The UK *space* sector supports economic activity and everyday living by: (i) generating GDP; (ii) providing employment opportunities; (iii) influencing technologies in other sectors; and (iv) increasing the productivity of individuals and businesses through satellite-enabled services. Nevertheless, there has been no academic research on the competitiveness of this sector. This chapter addresses this gap in the research by identifying the sources of competitiveness for UK satellite companies. Outlining the industry's governance and organisation of production is a core part of this, since the three areas are closely linked. For example, government policies influence the "nature of competition" and can provide solutions to negative lock-in (Chapter 5) (Nachum, 1998:465). Similarly, a lead firm's decision on whether to vertically integrate a production project impacts on their competitiveness (Chapter 6) (Gereffi *et al.,* 2005). Accordingly, this chapter draws on the research findings from the previous empirical chapters.

The approach taken in this chapter to understand competitiveness is to blend theory from both the RBV (Barney, 1991; Peteraf, 1993; Hervas-Oliver and Alboras-Garrigos, 2007) and evolutionary literature (Frenken and Boschma, 2007; Jensen, 2010; Phelps and Fuller, 2016). As a consequence, this chapter identifies five internal resources that are a source of competitiveness for UK satellite companies, whist highlighting the routines which develop and access them. The five internal resources are: (i) orbital slots and frequency spectrum; (ii) heritage; (iii) innovative capability; (iv) networks; and (v) capital. They were identified as drivers of the industry's competitiveness by the interview participants and whilst they are discussed separately in the chapter, it is appreciated that they are not isolated. Indeed, the resources support and affect the performance of one another (Hölzl; 2005; O'Regan, and Sims, 2008). There are other more standardised resources which are also important to the survival of UK satellite firms but are not explored in this chapter, since they are not distinctive factors that differentiate the firms from their competitors.

Chapters 4 and 6 have highlighted that satellite manufacturers, operators and application providers manage their own production projects and tasks. Consequently, there are different blends of competitive resources and routines across the three sub-sectors, which results in a distinctive set of competitive advantages in each. This chapter accounts for these variations by differentiating between the sub-sectors, when discussing the competitive resources and routines.

7.2. Accessing Coordinated Orbital Slots and Frequency Spectrum

This section explores the first of the five internal resources which are a source of competitiveness for UK satellite companies, identifying the value of the orbital slots and frequency spectrum, and the methods for accessing them. It also outlines the shared characteristics between property on Earth and slots/spectrum in *space*. It focusses specifically on UK satellite operators, since they are the agents who 'own' orbital slots and frequency spectrum. Nevertheless, manufacturers' contracts and application providers' services are indirectly dependent on the operators accessing slots and spectrum. Consequently, coordinated orbital slots and frequency spectrum are competitive assets which have an impact on the entire UK *space* sector.

7.2.1 Orbital Slots, Frequency Spectrum and Property

The provision of a fixed satellite service (where the satellite has a fixed position relative to the Earth's rotation) is dependent on the operator having access to a geostationary orbital slot and a portion of radio frequency spectrum (Chapter 5, Section 5.3). If the operator's satellite does not occupy a fixed position, then they are required to file for "*an altitude or an inclination"* in lower Earth or medium Earth orbit, as well as, for their portion of frequency spectrum (Chapter 4, Section 4.3.2). Both orbital slots and frequency spectrum are key sources of competitiveness in the UK *space* sector. By way of example:

> "*It's the equivalent of getting land in a real estate business, you can have the vision of building a huge building, but if you don't have the land to build it on then you can't go further. The same with this business, without spectrum and orbital slots you can't move forward*" (S.Operator2a).

UK satellite operators are allocated orbital slots and frequency spectrum by the ITU. Allocation of a slot or spectrum, grants an operator exclusive rights to the resource for the lifetime of its satellite (usually 15 years) (S.Operator1b). Typically, the operators then just "*keep refiling*" for the slot and replace old satellites with new ones (GovRegulator1). Consequently, "*for all practical purposes they keep* [the orbital slot or frequency spectrum] *indefinitely*" (S.Operator2a). Notwithstanding that the operators do not own the orbital slots or frequency spectrum, they do have ownership over rights to the resource; it is just a "different kind of ownership" (Sayer, 1995:147). This is interesting considering that the Outer *Space* Treaty (Article II) prohibits "national appropriation by claim or sovereignty*"* of orbital slots and frequency spectrum (Chapter 5, Section 5.2) (UNOOSA, 2016).

The form of ownership the operators have over orbital slots and frequency spectrum means that the *space* assets (orbital slots and frequency spectrum) share similar characteristics to property on Earth (see Table 7.1). For example, both have a use and exchange value, are in fixed supply and have a distinctive geography (Chapter 4) (Fortescue *et al*., 2003; MOD, 2010). As a result, owning the rights to orbital resources presents satellite companies with similar competitive advantages to owning property. For instance, both have the potential to "differentiate" firms and their competitors (GAO, 2011).

Table 7.1: The Similarities between Property on Earth and Slots/Spectrum in *Space*.

Characteristics	
Property	**Orbital Slots/Frequency Spectrum**
Property possesses: (i) a use value; and (ii) an exchange value.	Orbital slots/spectrum possess: (i) a use value - as they provide a return on investment through the sale of satellite data and bandwidth. Additionally, satellite-enabled applications contribute to business and society; (ii) an exchange value - as both are bought, sold and leased as a marketable commodity.
"… Property is fixed in *space* and has a considerable life expectancy. It can therefore be used as a store of wealth" (Bryson, 1997:1440).	- Orbital slots are fixed positions relative to the Earth rotations. - Over time, DTH providers become locked into services from specific orbital positions because their customers' satellites dishes are pointing in a particular direction (Chapter 6).
- There are varying rates of potential profit obtainable from land (differential locational advantages) (Scott, 1980:4). - High density of property is associated with high land prices (Storper, 2014:13).	There are differential locational advantages in *space* too. - Operators with the rights to valuable orbital positions (in the geostationary orbit) 'stack' their satellites to maximise the use of *space*.
"The property development process is inherently speculative; its foundation resting on the capitalisation of future streams of rental income which may never materialise" (Bryson, 1997:1442; Adams, 2004).	- "The priori system allows nations to claim future rights to orbital slots, based on certain criteria, even when they do not yet have the capability to enter those slots" (Trapp, 2013:1702). - In the time it takes to design, manufacture and launch a satellite (typically 7 years) customer

	needs and business plans can change to such a degree that operators may no longer require the orbital location/frequency they filed for (GAO, 2011:27).
"Every additional capital investment in the built environment rests on decisions which are constrained by previous infrastructural and building investments…" (Bryson, 1997:1443).	There are limits to the orbital slots and spectrum available, since operators are forbidden from interfering with existing "satellites and other users of spectrum" when launching a new service (Thompson, 1996:284).
Without property maintenance there will be a depreciation of rental value (Wilhelmsson, 2008).	Once a satellite's fuel runs out, it will eventually drift into *space* and out of operation. There is also technical obsolescence where the satellite's technology is no longer superior to that available in the market. Consequently, operators maintain the use value of their slot/spectrum by launching new satellites.

Source: Author.

Table 7.1 highlights the similarities between property, orbital slots and frequency spectrum. This link contributes to the vertical geopolitics work, which explores the "height and depth" of territories (Weizman, 2002:3; Elden, 2013:49). The next sub-section outlines how slots and spectrum are accessed by UK satellite operators.

7.2.2 Accessing Orbital Slots and Spectrum

The three-stage formal process for applying for orbital slots and frequency spectrum was outlined in Chapter 4 (Section 4.3.2). The process is managed by the ITU and enforced by national IRAs (Chapter 5, Section 5.5). It follows a 'posterior system' of first-come, first-served, whereby if an operator's competitor "*files by just a day before you*" then they have priority (Cahill, 2000; S.Operator2a). The posterior system benefits mature operators in the market who applied for their orbital slots a number of years ago. Consequently, there is a first-mover advantage (FMA) to slot and spectrum allocation (Chapter 5, Section 5.3). For example, the largest UK operator was previously an inter-governmental organisation founded in 1975. This "non-profit co-operative of 28 countries" was allocated four geostationary slots (Warf, 2007:391). When the operator was privatised in April 1999 it kept its slots, giving it FMA over new entrants. This attribute from the firm's past, is a characteristic of the firm's heritage (Urde *et al*, 2007; Billing, 2013). Heritage is an intangible resource that is a key driver of competitiveness in the UK *space* sector (Section 7.3). The overlap between orbital slots/spectrum and heritage is evidence of the interactions between competitive resources.

However, mature operators cannot rely on existing filings when launching new services. Likewise, younger operators have to rely on other routes for securing slots and spectrum. One way in which the operators secure slots/frequency spectrum is by leasing capacity from a competitor's satellite, which is appropriately positioned to give access to the required footprint. This has the advantage of enabling the operator to avoid the high costs of manufacturing and launching their own satellite. Nevertheless, the arrangement can make the operator vulnerable to a competitor "*pushing up prices*", which can impact on the price of the service it is providing for its customer (L.Prime1d).

Operators can also increase their chances of securing favourable orbital slots and frequency spectrum by locating in certain jurisdictions (Chapter 5, Section 5.3.1). This is a resulting factor of nation states having a central role in determining the use/allocation of *space* and having the freedom to interpret due diligence criteria of ITU guidelines in their own way. Consequently, there are certain jurisdictions in which operators will locate that are more relaxed in their regulatory approach and are more likely to allocate orbital slots/frequency spectrum to the operators. This jurisdiction selection can disadvantage UK based operators who have to apply through a compliant Ofcom. Therefore, they are often left with the option to "*pay a lot of money for slots"* or frequencies from other operators on the "*orbital market*" (M.Operator1b).

In addition to offering money, operators 'paper file' (reserve orbital slots or frequency spectrum, without intention for their actual use) slots/spectrum, which they use to negotiate with their competitors for other slots/spectrum. The implications of paper filing and the loopholes in the administrative due diligence criteria, which allow them, were explored in Chapter 5 (Section 5.3). S.Operator2a likened the negotiating process of paper slots to a "*card game*":

> "*…your competitor might not have any interest in their orbital slot, but they might have interest in other areas and be able to trade, so that is the purpose of why you file so many, you can't play a card game with one card, you need to have different things to play with in order to be able to communicate*" (S.Operator2a).

This evidence of orbital slots and frequency spectrum being bought and exchanged as a marketable commodity suggests a "system of functional property rights" in *space* similar to that on the ground (Cahill, 2000:238). This reinforces the similarities between property on Earth and slots/spectrum in *space* (Table 7.1).

Operators also secure orbital slots and spectrum through acquisitions of other satellite operators, which widens their resource base. For example, one of the UK based operators recently acquired a "*Mexican satellite operator who had three orbital slots over Latin America*" (L.DTHApplications1). This was valuable because it meant that suddenly they *"had really good coverage over Latin America and North America"* and access to a new market (L.DTHApplications1). When operators acquire another company they are also "*buying people, contracts, the satellites and some of the infrastructure on the ground*"

(S.Operator3c). The RBV literature also identifies how "organizationally embedded knowledge" is gained when acquiring another firm (Mariotti *et al*., 2014:189). Consequently, acquisitions are very common in the satellite industry, with some operators finding it can be "*easier to grow through acquisition*" rather than launching their "*own satellite*" (S.Operator3c).

The operators' use of their allocated orbital slots and frequency spectrum is dependent on a launch provider successfully delivering satellites to the appropriate orbit and position. Additionally, it depends on the operators having access to ground stations, which contain the support systems that send commands up to satellites and receive payload data on the ground (Chapter 4, Section 4.5.1). The satellite's orbit defines the 'ground track', which dictates the geographical position required for the ground stations, and the nature of the mission determines how many different ground stations the satellites need to communicate with (MOD, 2010). Without satellite infrastructure, launch vehicles and ground stations, the value of orbital slots or frequency spectrum cannot be realised. This highlights the significance of tangible resources to the competitiveness of the *space* sector. This furthers the RBV debate, which argues that tangible resources are a "relatively poor source of advantage" (Fahy, 2002:64). In practice, tangible assets (such as ground stations) support intangible assets (such as orbital slots/frequency spectrum) and the two cannot be separated.

7.2.3 Section Overview: Orbital Slots and Frequency Spectrum as Sources of Competitiveness.

This section has identified the following routes UK satellite operators take in order to access orbital slots and frequencies, namely: (i) formal process; (ii) leasing capacity; (iii) buying and exchanging on the orbital market; and (iv) acquisition. These four competitive practices are not routines because they are not everyday, predictable behavioural patterns (Jensen, 2010; Maskell and Malmberg, 2007; Boschma and Frenken, 2006). Instead, they occur only when an operator needs to launch a new service, which on average is every five years. This distinction between a routine and a competitive practice is important, since the literature has done little to define explicitly what is and is not a routine.

The expense and effort involved in accessing orbital slots/ frequency spectrum is reflective of the use and exchange value of the *space* assets. Slots and spectrum are valuable because they are finite resources that have the potential to differentiate operators from their competitors (GAO, 2011; S.Operator2b). Orbital slots/spectrum also provides a return on investment through the sale of satellite data and bandwidth. This return differentiates (increases or decreases) between locations, which is consistent with the characteristics of property (Scott, 1980). However, unless satellite infrastructure, launch vehicles and ground stations are in place the value of orbital slots or frequency spectrum cannot be realised, emphasising the interdependency between tangible and intangible assets.

The next section explores heritage as a competitive resource. This was found to interrelate with accessing orbital resources, as the more mature UK operators have orbital slots/spectrum "*through their heritage*" (M.Operator1a).

7.3 Heritage as a Source of Competitiveness in the UK *Space* Sector

A satellite is launched into orbit under the following extreme conditions: (i) high levels of vibration; (ii) mechanical shock; (iii) temperature gradient of up to 200°C degrees; and (iv) rapidly declining pressure (Fortescue *et al.*, 2003:12). Together with the harsh in-orbit environment, this exposes satellites to a high risk of disruption or failure (Royal Academy of Engineering, 2013). Satellite manufacturers and operators try to mitigate these risks as much as possible. Risks are reduced by the satellite companies prioritising suppliers and components with "*heritage*" (GovPolicy3a; M.Prime1a).

Heritage is an intangible resource, characterised by attributes from a firm's past that are relevant to its contemporary context and purpose (Urde *et al*, 2007; Billing, 2013). For satellite manufacturers and operators, the most relevant attribute from a firm's past is its 'flight history' or the number of satellite missions that it or one of its products has been involved with. Flight history signals competence-based trust (defined as the perception of partners on whether they will effectively contribute to a relationship) to stakeholders (Billing, 2013:53) and affords "firms a 'higher-status' in the market" (Boschma and Martin, 2010:282). This relationship aligns with the evolutionary perspective of how previous actions and decisions "affect the probability" of the future behaviour of firms (Boschma and Frenken, 2006:280). It highlights why it was important to blend two sets of literature in this chapter, since the evolutionary perspective explains heritage, whilst the RBV has overlooked it as an intangible resource.

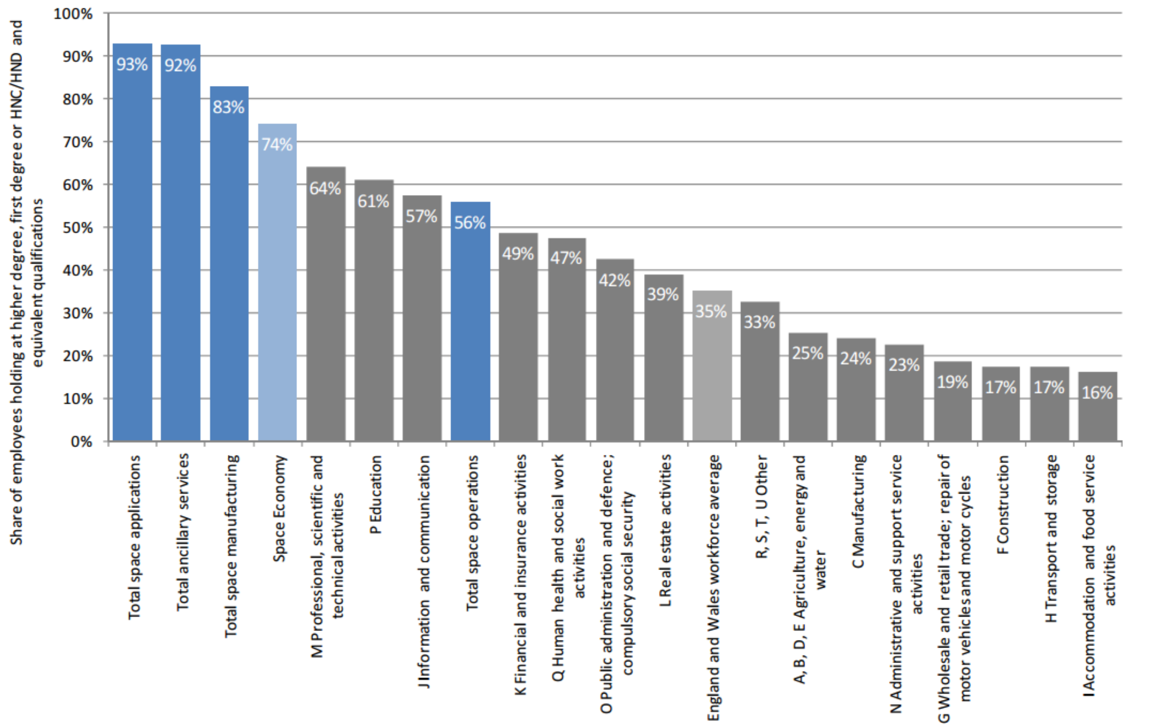
Heritage has two forms: (i) the heritage of a firm (including relationships); and (ii) the heritage of individual products. These two forms were identified during analysis of the interview transcripts; they often occur simultaneously, but can also be independent. Both forms signal competence-based trust to consumers (Boschma and Martin, 2010). Competence-based trust is important because it impacts on reputational assets (corporate reputation, brand equity etc.) and thus firm-level competitiveness. Nevertheless, heritage in the context of corporate competitiveness has been largely ignored and is not identified in the RBV literature (Billing, 2013). The only exception to this is Tokatli (2012:61) who explored heritage in relation to retro fashion (Tokatli, 2012; De Vaan *et al.*, 2012). Additionally, De Vaan *et al.* (2012) argued that heritage brings the 'advantage of experience'. Therefore, further research is required to fully explore heritage as a source of competitiveness.

The remainder of this section identifies what makes heritage a competitive advantage and how it is developed in the UK *space* sector. It focusses on satellite manufacturers and satellite operators, since heritage is more relevant to the sale of a satellite, compared to other BSRs in the sector (Chapter 6). Nevertheless, service providers (particularly DTH providers) are under pressure to choose reliable operators to supply them with bandwidth/data for delivering a good service to their customers (L.DTHApplications1). Therefore, heritage can also factor into the sale of satellite-enabled services.

7.3.1 Heritage as a Source of Competitiveness

Heritage is the "*back bone*" of competitiveness for UK satellite manufacturers (M.Prime2), since it is protected from imitation and thus, provides a sustainable source of competitive advantage (Boschma and Martin, 2010; Singh *et al*, 2008; Starr *et al*, 2003). For instance, flight history demonstrates that a manufacturer has had experience in other missions. This experience cannot be imitated and supports the development of expertise, signalling reliability to key customers and encouraging 'competence-based trust' (Galbreath, 2005; Mascitelli, 2000; Turban *et al.*, 1998). Where there is a high degree of competence-based trust because of heritage, buyers are attracted and repeat "loyal purchasing" is encouraged (Kennedy *et al*, 2001:75). For example, for an operator "*spending $500-600 million on a satellite, they don't want it to break*" so will be attracted to a manufacturer whom they trust to be competent (M.Prime1a). It is important to the operators to "*de-risk the programme as much as possible*" because satellites are a "*massive investment*" (S.Operator2b). In addition, there is the added complexity that once satellite technology is launched "*you never see it again*" (L.Prime2b). This situation is unlike other high-tech industries and encourages a preference for proven technology because if something goes wrong "*you can't go up there and fix it*" (L.Prime2b). Furthermore, as discussed in Chapter 6 (Section 6.4.2), heritage impacts on the insurance and licensing process which precede a satellite application's delivery to market. This example highlights the three-way relationship between governance (insurance and licensing process), organisation of production (procurement decisions) and competitiveness.

Manufacturers with heritage are also advantaged because they are 'well-known' in the market, which motivates other firms to collaborate with them and research centres to approach them "with ideas and proposals" (Walsh and Beatty, 2007:127; Billing, 2013:53). This helps firms to form a network of partnerships (Section 7.5) that are used to access external knowledge and drive innovation (Section 7.4). Manufacturers with heritage are also more likely, than firms without heritage, to attract a highly qualified workforce (M.DataApplications1d). This is significant as attracting and retaining human capital in any industry, provides "firms with a sustained competitive advantage" (Turban *et al*, 1998:25). The demand for highly qualified employees is also greater in the *space* sector, compared to other sectors (as illustrated in Figure 7.1).



Note: Space economy and sub-segments based on respondents to Size and Heath of the UK Space Industry 2014. For comparability, Higher Degree, First Degree and HNC/HND have been combined.

Figure 7.1: Share of employees with higher degree qualifications in the *space* sector compared with other sectors.

Source: London Economics (2015:23).

Competence-based trust is also critical for “convincing external financers to lend money or invest” in a manufacturer or operator, which is a critical source of competitiveness (Section 7.6) (Billing, 2013:53). Manufacturers gain competence-based trust by highlighting their experience and the flight history of their products, whilst operators encourage competence-based trust through procuring a satellite manufacturer with heritage. It also helps if operators can demonstrate their own heritage, in terms of experience of effective service provision. All of the above examples of stakeholders responding to trust signals is evidence of how “heritage offers firms a ‘higher-status’ in the market” (Billing, 2013:53). Consequently, ‘accumulative advantage’ applies, whereby firms that have had early successes in the industry are advantage creating in the present market (Podolny, 1993;

Powell and Snellman, 2004). This is a development of the examples given of competitive advantages in the RBV literature. However, it aligns with the evolutionary perspective which argues that a firm's innovation potential is dependent on its "existing variety" of capabilities and assets (Frenken and Boschma, 2007:636).

7.3.2 Developing Heritage

The competitive advantages associated with heritage mean that UK satellite manufacturers are keen to maintain and develop it (and operators are keen to encourage this) through their everyday practices/routines. Developing heritage takes time, since it involves input by a product or a firm in several satellite missions, over a number of years. This means the product or manufacturer must remain competitive for a lengthy period of time. However, they must first secure a 'first flight' on a satellite mission. This is far from straightforward, since without heritage, stakeholders (customers, investors, collaborators etc.) are unlikely to trust the product or firm. The outcome is a 'chicken and egg' type scenario, since a product or manufacturer have to be involved in a satellite mission to develop flight history, but without heritage are unlikely to be considered as flight-ready (Billing, 2013). UK satellite manufacturers overcome this barrier by giving their "first sale for free" and paying for their own test flight (Billing, 2013:55). It is also possible for a satellite manufacturer to acquire heritage through mergers and acquisitions. However, these are all expensive options, with no guarantees of success.

An alternative option is for firms to bid for institutional grants and projects, funded by the European Commission and ESA. These facilitative forms of governance were discussed in Chapter 5 (Section 5.4.2) and are advantageous to manufacturers because they support technological developments. For example, M.Prime1 has benefited from ESA having funded "*a test model going up* [into orbit]" of its new generation satellite. This would have been more difficult for M.Prime1 to have achieved commercially "*because with insurers it is just impossible*" for them to support the launch of new technologies, without issuing "*unaffordable premiums*" (M.Prime1a). This demonstrates a positive impact of governance on the competitiveness of UK satellite companies. However, institutional support is not available for every project and smaller companies are often under-resourced to be able to cope with the grant applications. Therefore, often larger, well-established manufacturers are advantaged in accessing support for developing their flight history. This means that the barriers to entry are high in the industry.

Once manufacturers have developed their heritage they have to sustain it. Like reputation, heritage is precarious and can be quickly undone. Manufacturers maintain their heritage through minimising risks by making only incremental changes to their products/process. This impacts on their innovative routines (Section 7.4) and leads to technological lock-in. Technological lock-in describes when a firm becomes locked into a particular technology or 'technological regimes', even when 'superior' solutions might be available (Martin and Sunley, 2006; Cecere *et al*., 2014). It is an example of path dependency, where a firm is unable to "shake free of its history" and develop beyond their "established ways of doing things" (Martin and Sunley, 2006:400). However, there are also instances where there are breaks with heritage and radical innovation can prevail. Section 7.4 identifies these breaks with heritage.

7.3.3 Section Overview: Heritage as a Source of Competitiveness

This section has identified how heritage encourages competence-based trust and offers UK satellite firms a "higher-status in the market" (Billing, 2013:53). Consequently, heritage is "*a very powerful competitive advantage*" in the UK *space* sector (GovFacilitator2d), and thus it is important that manufacturers and operators maintain and develop it through their routines. This is a valuable contribution to the RBV literature, which has previously overlooked heritage as an intangible competitive resource.

The next section explores innovation as a source of competitiveness for UK satellite manufacturers, operators and service providers. It identifies that the majority of UK satellite manufacturers make only minor changes and improvements to their products and processes (Summerer, 2011). This is partly because of the manufacturers' reliance on existing knowledge, but is primarily because of technological lock-in, caused by the preference of buyers for products with heritage. This relationship between heritage and innovation aligns with the evolutionary perspective of how previous actions and decisions "affect the probability" of the future behaviour of firms (Boschma and Frenken, 2006:280). Nevertheless, whilst technological lock-in is difficult to overcome, it is "often a temporary phenomenon from which escape is possible" (Van der Vooren, 2012:101). Therefore, Section 7.4 also outlines the impact of heritage on innovative routines and where technological lock-in has been overcome in the UK *space* sector.

7.4 Innovation in the UK *Space* Sector

Innovation involves renewing either a firm's product design or production process through the "commercial application of new knowledge" (Love *et al.*, 2011:1438). It is a source of competitiveness, as it is a means for firms to better meet the needs of their customers. Innovation does this through addressing "key buying criteria" (Hall, 1993:607), such as reduction in lead time and costs (Ireland and Webb, 2007). A firm's innovation potential is dependent on its dynamic, innovative capability, which forms a part of its internal resources (Vega-Jurado *et al*., 2008; Damanpour *et al*., 2009). A firm's innovative capability is a product of its innovating routines, which include: (i) "co-ordinating technological resources external to the firm"; and (ii) "adapting organisational practices to the requirements of radically changing technological opportunities" (Pavitt, 2002:119). These practices are "regular and predictable behavioural patterns" because innovation is a constant as firms continually challenge their "existing processes and products" (Bryson and Taylor, 2010:586). The interaction between innovative capabilities and innovating routines demonstrates the overlap between the RBV and evolutionary literature.

A firm's innovative capability is also conditional to its other assets (Vega-Jurado *et al*., 2008; Damanpour *et al*., 2009). For example, innovation depends on the firm being able to access knowledge and find "*a supply of the right people*" with sufficient skills and qualifications (GovPolicy3c). Similarly, firms require access to capital to fund necessary changes to products or processes (Hansen *et al*., 2014). Networking is crucial to accessing these assets (Section 7.5), and heritage helps with network formation. These examples highlight the interplay between competitive routines in the industry.

There are two types of innovation: incremental ("minor changes and improvements") and radical (new "engineering and scientific principles") (Summerer, 2011:7). Both types are advantage-creating, although radical innovation does have a greater impact (Parida *et al*, 2012; Legnick-Hall, 1992). Nevertheless, the evolutionary literature argues that the majority of firms will innovate incrementally, so as to continue to "exploit their knowledge built up in the past" (Boschma and Frenken, 2006:278). This argument is consistent with the research findings on UK satellite manufacturers, as the majority of firms make only minor changes to their products, so as to draw on their existing knowledge and maintain their heritage (Summerer, 2011). However, varying market conditions impacts on innovation potential (Caryannis and Provance, 2008; Jones and Craven, 2001). Consequently, distinctions can be made between the innovative practices of firms that manufacture telecommunications satellites and those that manufacture Earth-observation satellites. These differences are highlighted in the next sub-section.

7.4.1 Innovation by UK Satellite Manufacturers

The research into the manufacturing sector focussed specifically on the four UK-based prime contractors, responsible for the final integration of platforms and payloads into complete satellites. Subcontractors, who supply components and materials to the primes, are typically more price sensitive and have different innovative routines (Billing, 2013).

UK primes are under pressure to provide a degree of certainty for their customers by minimising, where possible, the high risks associated with *space* activity (Todd, 1992). This relates back to the value placed on heritage in the industry and how failure of a satellite would cause "*huge reputational damage*" for a manufacturer (M.Prime1a). Consequently, UK manufacturers are typically incremental in their approach to innovation, as their customers' preference for proven technology means they purposefully select mature systems and components in their design (Fortescue *et al.*, 2003). This is linked to the operators' needs to minimise insurance premiums and obtain *space* licenses. However, distinctions can be made between innovation in the telecommunications and observation markets. These differences in approaches to innovation can be explained by varying demand conditions (what the customers want) across the different market sectors. Navigation satellites are not discussed, since they are funded entirely through public procurement projects and the focus here is on firm competitiveness in commercial markets.

Telecommunication Satellites

Communication satellites are the largest and therefore the heaviest and most expensive variety of satellite to launch (Chapter 4, Section 4.2.2). They also most commonly operate in the geostationary band, which is the most costly orbit into which to launch a satellite. Therefore, telecommunication operators "*weigh heavily on heritage*" and encourage the designs of their satellites to be as conservative as possible (L.Operator1b). To S.Operator1b: "*... everyone wants to use what is flight proven technology, so we are all pretty risk-averse*". Consequently, the manufacturers make only incremental changes to the designs of their communication satellites to maximise reliability and attract customers (Fortescue *et al.,* 2003:241). This also helps them to reduce the risk of their satellites failing, which is important since:

> "*If it fails within a year, we* [the manufacturer] *are still locked into a contract… the operator is owed 90% of the contract, in 3 years 80% of the contract…*" (M.Prime1a).

These risks present high barriers to radical innovations, as manufacturers are locked out of using technologies without heritage (Cecere *et al*., 2014:1041). The mature technologies they instead rely on are not necessarily the most efficient solutions in the market, leading to higher production costs (Martin and Sunley, 2006). In other industries these higher costs would cause firms to "struggle to compete and survive" (Cecere *et al*., 2014:1042). However, heritage products are valued so highly that satellite manufacturers can "charge premium prices" and still make a profit (Fombrun and Shanley, 1990:234). There currently "*isn't the competition to drive down these prices*" and encourage more radical, cost-saving innovation: "*if we can charge £200 million then of course we will*" (L.Prime1b).

Overall, the incentives for disruptive innovation in the telecommunication sectors are low (Adlen, 2011; Van der Vooren, 2012). Rather than "*creating something from scratch*" through radical innovation, manufacturers will "*tweak*" existing satellite designs in an incremental way (S.Operator2b). These 'tweaks' typically focus on maximising capacity and increasing the "*processing power of the satellite*" (L.Operator1a; L.DTHApplications2). For example, stacking a number of different antennae onto a single satellite to increase capacity. This helps "*one satellite go further*" and is a response to the need of the telecommunications operators to "*pack as much as they can into this one orbital slo*t" (L.Operator1a; L.Prime1c). This is important because of the value of orbital slots and because a telecommunications satellite is such a "*massive investment*" that has "*got to last for fifteen years*" (S.Operator2; L.Prime2).

There are examples of breaks with heritage in the telecommunication sector. For example, a recent 'tweak' by the larger primes has also been the development of electrical propulsion, which is a response to the EU banning (as of 2020) of hydrazine, "*the main propellant in chemical propulsion systems*" (M.Prime1a). This is an example of where regulatory governance (Chapter 5) has helped to overcome negative lock-in and impacted on the innovating routines of UK satellite manufacturers. In this case regulation has been "*a force for good*", motivating the industry to move away from the old chemical propulsion technology (GovPolicy3e). However, there is not the same drive for changes to other aspects of a telecommunication satellite's design.

Earth Observation Satellites

Observation satellites are not confined to the geostationary orbit (GEO), unlike most telecommunication satellites. They instead operate in the low-Earth orbit (LEO), which has high resolution and sun-synchronous capabilities (Table 4.3). Launches to this orbit are lower in cost, thus there is market demand for the satellites to be cheaper so that the cost benefits of launches are not outweighed. The lifetime of a satellite in LEO is also much less than in GEO because of greater atmospheric drag leading to orbital decay: "*they do not last long, typically five years say*" (S.SystemsManufacturer1a). This means that Earth observation operators have to replace their satellites more frequently and so demand them at a lower cost.

Demand for reduction in cost has driven the "development of small satellite technology" by two UK primes (Fortescue *et al.*, 2003:2). Smaller satellites have a reduced weight, which is advantageous because the lighter the *space*craft, the cheaper it is to launch. Cost is also reduced by standardising the production process and satellite designs "*as much as possible*" (L.Prime2a). This standardisation increases efficiency and is an example of a process innovation, which reduces the time to market for the satellite and saves on costs. This standardised approach contrasts with the manufacturing of more expensive satellites which typically has "*no concept of a production line*" (L.Prime1b). It is possible because more Earth observation, than telecommunications, components can be made in-house:

> "*Our supply chain on the EO* [Earth observation] *side is very, very low. On the Geo* [telecommunication] *side it's quite different because they have to be space qualified* [have heritage]*..., so we've got to buy in some stuff*" (L.Prime2b).

Lower costs reduce financial risks, encouraging innovation that is path changing and creates opportunities for heritage to be put to one side. For example, the use of *"more cutting edge components*", which drives the production of even smaller satellites (UK cubesats are 10x10x10 centimetres) (M.Prime2a). Additionally, because the Earth observation market focusses on exploration, rather than reliable communications, the unknown aspect of the missions stimulates technological innovation. By way of example:

> "*Rather than what is proven technology, we ask questions like: What the latest widget does? What sort of thing can I measure? What sensor can I put up there?"* (L.Prime2b).

This contrasts to a telecommunications satellite with which "*you have to manage risk more closely, use older, special components*" (M.Prime2a). However, smaller satellites "cannot cater for all mission objectives" (Foretscue, 2003: 583). For example, telecommunications require power systems and antenna arrays that are too large to be carried by a small platform. Smaller satellites also have a much shorter lifespan (Chapter 4, Section 4.2.2).

These examples provide evidence that innovation in respect of Earth observation satellites is less incremental than telecommunication satellites. This highlights the impact of demand conditions and also *space* geography (in terms of orbits) (Chapter 4, Section 4.3) on innovative routines and how there is varying innovation potential between different satellite markets (Webster, 2004). The next section focusses on the innovating practices of UK satellite operators.

7.4.2 Innovation by UK Satellite Operators

Innovation by UK satellite operators is explicitly linked to that of the manufacturers, since the operators finance the satellites and outline their market needs to the manufacturers. They also have significant input during the design phase through their relational type BSRs (Chapter 6, Section 6.4.1). Consequently, UK satellite operators view technological changes to satellites as part of their innovation:

> "*It is one of the challenges of the sector to provide more for less, it does cost, but we try and counteract that by innovation, by simplifying our own systems, by having more power and lower cost satellites*" (L.Operator1d).

Accordingly, the examples of product innovations by manufacturers in Section 7.4.1 are also evidence of the competitive routines of UK satellite operators. Their innovation potential will vary depending on which satellite market they operate in.

Alongside technological innovations, UK operators "*respond to demand issues*" and "*the complexity of* [their] *customers' needs*" through changing the frequency bands and orbits in which their satellites operate (L.Operator1d; M.Operator1a). Part of their everyday practices is to plan for these developments by exchanging ideas with manufacturers about what is technologically possible. This exchange of information is typically part of the post-sale feedback in long-term, relational type BSRs (identified in Section 6.4.1). The satellite operators also have to apply for and coordinate orbital slots and frequency spectrum (Chapter 5, Section 5.3). Table 4.3 (Chapter 4) outlined the varying characteristics of different orbits and frequency bands available to satellite operators, and which are relevant to particular applications. When targeting new markets, operators must ensure their satellites are in the right frequency band and orbit. Therefore, operators must constantly track market demand, cope with uncertainty and respond to any changing customer needs. By way of example:

> "*In 2008-9 the US navy were saying they would no longer consider anything under eight kilobits per second to be broadband, which was handy because we had just spent £1.5 billion launching a five kilobits per second network. This led us down the very difficult path of having to invest another £1.6 billion in three satellites in the Ka-band which gave us the greater bandwidth we needed*" (L.Operator1a).

This is an example of where changing customer needs have prompted innovation.

Another UK based operator is the only satellite service provider to operate a "*constellation in medium Earth orbit*" (S.Operator2c) (Chapter 5, Section 5.4.1). Medium Earth orbit has lower latency ("time it takes for information to transmit from the Earth to the satellite and back again") than the geostationary belt (O3B, 2016), allowing the telecommunications operator to "*deliver fibre like services*" (S.Operator2c). This is an innovative approach, disregarded by other operators because of the high levels of radiation and non-geosynchronous properties of the medium-Earth-orbit. This operator has found that one of the biggest challenges has been *"getting the customers to invest in something new*" (S.Operator2a). This demonstrates that the preference for heritage also translates to the operating segment of the UK *space* sector. The operator has overcome this challenge through proof of concept exercises. This is a form of 'functional upgrading' and involves the operators delivering some applications to demonstrate the functionality of their satellite to their customers and insurers (Chapter 6, Section 6.3.2). They also rely heavily on a network of start-up investors and parent company support, which has helped the operator to overcome path dependency. Additionally, to reduce the risks the operator has procured a satellite platform with a "*decent amount of heritage*" from another programme (S.Operator2c). Similar to the manufacturing sector, innovation by operators relies on the appropriate skill-set amongst the labour force and "*a pool of knowledge*" (S.Operator1b). Accessing this knowledge relies on networks, the value of which is explored in Section 7.6.

7.4.3 Innovation by UK Satellite Application Providers

Innovation by satellite manufacturers and operators increases the "*available bandwidth on telecoms satellites"* and the "*accuracy and the frequency of EO data*"

(L.DTHApplications1; S.VSATApplications1). Therefore, much of the innovation impacting UK satellite applications is not carried out by application providers, but by other parts of the *space* sector. This re-emphasises the interdependency between the three sub-sectors of the UK satellite industry (Chapter 4).

However, application providers only benefit from the changes by manufacturers and operators if they "*keep up to date*" with technological developments and new datasets becoming available (Mi.DataApplications1a). This research is a critical part of their innovation routine and is supported through knowledge networks. If they are providers of satellite bandwidth, they also need to ensure they have obtained landing rights from the countries their signals are reaching. Similarly, Earth observation data providers are subject to export security regulations, which restrict data being sold to certain countries (Chapter 5, Section 5.7.1). Awareness of these regulations and compliance with any procedures (such as applying for landing rights) is an equally important part of application providers' innovation routines, highlighting how governance and competitiveness overlap.

The application providers also innovate by "*trying to do something different with the* [satellite] *data*" (M.DataApplications1c). This innovation, whilst on a much smaller scale compared to the changes made across the other industry sectors, is one of the most important firm-based routines driving the competitiveness of the UK industry. By way of illustration:

> "*… if you don't do anything with the data then there is no demand for satellites. That's what drives the demand and it's the usefulness of that that drives the whole value in the industry*" (L.Prime2b).

Satellite data innovation relies on "*algorithms*", "*computer power*" and "*a very talented group of people*" (S.DataApplications2; Mi.DataApplications3). This once again stresses the importance of access to skills and knowledge, which is facilitated through the management of networks.

As discussed in Chapter 5, innovation in this sector is also supported by facilitative forms of governance. For example, as part of the UK Space Agency's '*space* for a smarter government' programme, they have strategically procured satellite-enabled services. This stimulates the market by providing a customer for the satellite operators, whilst also attracting further investment through demonstrating to other customers the UK Space Agency's confidence in the application (Section 5.7.3).

Furthermore, the application companies find they are "*protected from competition*", which helps with innovation, because the sector is relatively young with few "*other businesses doing what* [they] *do*" (L.VSATApplications1). For example:

> "*We are not finding that there are people that are directly competing with us head on. People do similar things to us and provide similar data, but we haven't found anybody doing what we are doing at the present time*" (S.DataApplications2).

In summary, the service they are providing is currently very niche and part of an emerging small market. The application companies expect other similar firms to "*emerge over the next 12, 18 months"* as people realise the market potential and employees leave and establish their own companies (S.DataApplications2). However, although the structure of their BSRs are 'fluid' (Gereffi *et al*., 2005), the complexity of their sale transactions is still relatively high (modular type BSRs) (Chapter 6). Therefore, the application companies are confident that even when new competition emerges, their customers will not "*want to* *switch suppliers because that can cost*" (S.DataApplications2). This highlights how varying industry characteristics can impact upon competitive routines.

7.4.4 Section Overview: Innovativeness as a Source of Competitiveness

This section explored innovation in the manufacturing, operating and application sub-sectors of the UK satellite industry. It highlighted the different practices and approaches taken by the satellite companies, which is a factor of their industry specific features and varying market conditions (Carayannis and Provance, 2008; Jones and Craven, 2001). The research findings aligned with the RBV that a firm's innovation potential is dependent on its adoption of dynamic capabilities and its access to distinctive assets (Vega-Jurado *et al*., 2008; Damanpour *et al*., 2009:656). For example, innovation in the UK satellite industry relies on access to skills and knowledge. Knowledge is accessed through networks, which follows the argument that firm competitiveness is "multifactorial" and "cannot be attributed to only one resource" (O'Regan, and Sims 2008:410). Section 7.5 focusses on these networks and outlines the routines involved in establishing and managing them.

Section 7.4 also outlined the influence of heritage on innovation in the industry, as it encourages the manufacturers and operators to be incremental in their approach to change. This leads to a technological lock-in to older components and follows the evolutionary perspective on how previous actions and decisions "affect the probability" of firms' future behaviour (Martin and Sunley, 2006:401; Boschma and Frenken, 2006:280). However, since varying market conditions impact on innovative routines, distinctions can be made between innovation in the telecommunications and Earth-observation markets. Similarly, the innovation practices of application providers are less constrained by heritage (Chapter 6, Section 6.5). Additionally, there are also instances where there has been a break with heritage (Van der Vooren, 2012:101). For example, regulatory and facilitative forms of governance have helped firms overcome negative lock-in, whilst changing customer needs have also prompted innovation.

7.5. Network of Partners

UK satellite companies cannot rely solely on their internal assets and capabilities (Dahlander and Gann, 2010; Howells *et al*, 2012; Rusanen *et al.*, 2014). Instead, they must also rely on networks of partners to access knowledge and financial assets (Roper and Hewitt Dundas, 2012). Networks are relational ties held between firms and business actors, including research institutions and other companies (Jones and Craven, 2001; Pavlinek, 2015). They are used by a firm to secure "more resources than they actually control" (Ellis, 2010:5) and generate market opportunities (Hervas-Oliver and Albors-Garrigos, 2009). In doing so, networks provide a source of competitiveness (Henry, 2013; Alvarez *et al*, 2009). There are two sets of routines involved here, namely: (i) networking as a process; and (ii) if a relationships forms, the management of that relationship and other networks of partners.

This section explores the benefits of networking by satellite firms and how the networks are formed. There is considerable overlap with the approach to and motivations for networking by satellite manufacturers, operators and service providers. Therefore, the networking routines of the whole dataset are discussed collectively, except where specific examples are referred to. The focus is on partners who facilitate access to knowledge resources, since accessing finance is discussed in Section 7.6. The knowledge partners include: (i) universities; and (ii) and other satellite companies. Customers and suppliers are also an important part of the knowledge networks of satellite firms (Jones and Craven, 2001; Pavlinek, 2015). For example, the complexity of a commercial satellite transaction, demands close interactions and two-way exchanges of knowledge between a manufacturer and its buyer (Chapter 6, Section 6.4.2). These BSRs were focussed on in Chapter 6.

7.5.1 Networking for Knowledge and Data Resources

The complexity of satellite technology means that UK companies often rely on external knowledge to supplement their in-house expertise (Hansen, 2002; Laursen and Salter, 2006). There are two types of knowledge: 'tacit' which is experience based and relies on face-to-face exchanges; and 'codified' which can be exchanged and virtually at distance in the form of written documents (Christopherson and Clark, 2007; Kotabe and Murray, 2004; Howells and Roberts, 2000). In order to maintain competitiveness both types of knowledge are important, meaning firms often rely on both localised and distant exchanges (Bathelt and Cohendet, 2014). They source this knowledge through networking with two key partners: (i) universities; and (ii) other satellite companies. The *space* sector is an "*international endeavour*" (GovPolicy3a). Therefore, the networks of partners are also often international. However, where more regular face-to-face contact is required for the exchanges of tacit knowledge, geographically localised networks "*are preferred*" (GovFacilitator2e) (Christopherson and Clark, 2007; Kotabe and Murray, 2004; Howells and Roberts, 2000). Trade regulations also restrict networks with partners from certain countries where there are political conflicts and concerns around defence (Chapter 4, Section 4.2.2). These restrictions are exacerbated in a defence contract.

Universities conduct specialist research, which generates expert knowledge on a range of topics relevant to UK satellite companies. This knowledge is "*tapped into*" through technical papers, the hiring of PhD students and professional licensing agreements (Mi.DataApplications2). Networks between firms and the universities facilitate these three forms of knowledge exchange, with licensing agreements demanding comparatively stronger ties. The knowledge gained helps the firm to innovate and sustain or improve its market position (Fitjar and Huber, 2015; Bessant *et al*., 2012). Consequently, networking with "*universities is a very important part of* [their] *development*" (L.Prime2c). UK satellite firms often network with a number of universities, which are not always within close proximity, since they are chosen in accordance with their specialisms and expertise (Billing, 2013). For example, S.DataApplications2 "*deal with about six or eight universities"*:

> "*So for our work on agriculture we brought in Reading University, for flooding we brought in Oxford University, we could go through a list. We've identified the correct people that UK wise are at the leading edge*" (S.DataApplications2).

Networking with universities is valuable because alongside their knowledge sharing, they provide other forms of support (Christopherson and Clark, 2007; Ponds *et al*., 2010:233). For example, universities commonly allow access to their testing equipment, which would otherwise be an expensive external cost for manufacturers (Billing, 2013). Furthermore, it is productive for UK satellite firms to be able "*tap into"* the universities' network and connect with as many business actors as possible (S.DataApplications2).

In addition to networking with universities, partnerships with other firms are a "*critical*" source of external knowledge in the UK satellite industry (L.Prime2a). UK satellite companies partner with firms internationally "*who have clever and innovative ideas that* [they] *can leverage*" (M.Applications1b). They find that their expertise and the knowledge of their commercial partners "*complement each other*" and by joining forces they can both provide "*a better offering to* [their] *customers*" (S.DataApplications2; L.Prime2b). Therefore, networking with other firms maximises the resources available to UK satellite companies, which creates a competitive advantage. Partnerships with firms also create opportunities for gaining 'intelligence' or information on other firms, which is valuable when developing competitive strategies. By way of example:

> "*…just knowing somebody and trusting some other company that you can pick up the phone and call and say 'hey Bob, I heard that so and so company is getting ready to compete with us, what have you heard?*' (M.DataApplications1c).

Additionally, commercial networking helps satellite companies to be "*aware of lots of opportunities*", as they learn about the projects their partners are involved with (Mi.DataApplications3). It is "*a win, win situation when there is cooperation*" (S.Operator2a). For example, smaller satellite data companies typically "*work inside some large organisations* [manufacturers and operators], *helping them to develop better products*" (S.DataApplications2). In exchange, the smaller companies have the opportunity to sell their "*expertise on a larger scale*" and "*grow* [their] *customer base*" (S.DataApplications2). This demonstrates the advantages offered by networking to the UK *space* sector and how some of these networking partnerships function between application, operating and manufacturing companies. This highlights the interdependency between the three parts of the industry and how their competitiveness is linked.

Earth observation operators also benefit from forming a network or "*alliance with other satellite operators*" (S.SystemsManufacturer1b). The alliance partners agree to share data "*as part of a virtual constellation*", which enables them to guarantee "*an image within a day*" for their customers (M.Operator1b; S.SystemsManufacturer1b). Daily imaging is particularly important in the security/defence sector and would be difficult to achieve with a single satellite passing over an area, once a day when there may be cloud coverage.

Therefore, networking is critical for winning contracts that provide "*daily imaging capabilities*", and is thus a key source of competitiveness for Earth observation operators (S.SystemsManufacturer1b). These partnerships are often international and similar scenarios can be found in the telecommunication sector, with hosted-payloads (Section 7.3).

Networking is particularly valuable for smaller, younger firms, as it broadens their limited resource base and helps them to offset "some of their fragility" (Atterton, 2007:230). They have to be careful to protect themselves "*IP wise*" however, and avoid inadvertently supporting their direct competitors (S.DataApplications2). Additionally, a partner that was previously not a threat may develop into a competitor over time. Therefore, part of the networking routine involves adapting to changes to partners. For example:

> "*I've got a good relationship with one firm and they are keen to work with me, but they have grown from two people to twelve people in two years and some people in our company are now saying: 'hold on they might become a competitor, we shouldn't be working with them'* " (M.DataApplications1a).

The next sub-section outlines how the networks that contribute to the competitiveness of UK satellite companies are formed.

7.5.2 Network Formation

Network formation is a boundary spanning activity, where "random patterns of social activity" develop into relationships (Jones and Craven, 2001:40). The process demands varying levels of "trust, transparency and partner interaction", depending on the strength of the network ties (Henry, 2013:94). For example, stronger ties require closer and more frequent interactions, which facilitates greater "resource sharing" (Thune, 2007:160). In contrast, weak ties demand less interaction (Granovetter, 1973), but still "carry novel information" and uncover new opportunities (Thune, 2007:160). Networks are also either 'informal' or 'formal'. In informal networks, participants share "mutually reinforcing self-interests", but are not tied to any form of agreement (Kingsley and Malecki, 2004:75). As an illustration:

> *"It's just a company to company agreement. There is no contractual binding agreement or anything like that*" (L.Prime2b).

In contrast, participants in a 'formal network' explicitly agree on a "shared objective", which requires them to coordinate their actions and resources (Kingsley and Malecki, 2004:75). For example, M.Prime1 has a formal partnership with M.Applications1, known as the 'Space Alliance'. They share contracts and coordinate their actions and resources, while the manufacturer "*builds satellites*" and the service provider operates them (M.Prime1).

Networks are either formed strategically to address a particular need or emerge randomly from social interactions (Jones and Craven, 2001; Kingsley and Malecki, 2004). For example, the Space Alliance was formed strategically by the parent organisations which the manufacturing and service companies share. In contrast, other *space* networks have emerged randomly between firms that have employees or directors that have previously worked together (Jones and Craven, 2001; Francassi and Tate, 2012). However, it is difficult to always distinguish between networks which have been formed 'strategically' or 'randomly', since even when a firm strategically seeks-out networking opportunities there may be unexpected outcomes. This is the case for firms which have located in the Harwell *space* cluster. Clusters are defined as:

> "…geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate." (Porter, 2000:15).

The Harwell *space* cluster is situated immediately south of Oxford and is described as the "hub of the UK *space* industry" (Billing, 2013: 32) (Chapter 5, Section 5.7.3). Harwell is home to twenty-three *space* related organisations, including: (i) twenty private companies; (ii) the Catapult Satellite Applications Centre; (iii) the Rutherford Appleton Laboratory research and test facility; (iv) ESA's ECSAT centre; and (v) ESA's *space* business incubator (supports start-up companies with funding and workspace). This concentration of satellite organisations provides numerous networking opportunities for the companies based there permanently and also for firm representatives visiting the site. It is an example of a policy initiative (governance) producing a local lock-in of relationships. Network formation is supported by the cluster environment because it provides opportunity for face-to-face meetings. This is described as the 'richest' form of communication because it supports "verbal and non-verbal cues" and allows partners to share the same experience (Bathelt and Turi, 2011:525). This supports the exchange of 'tacit' knowledge, which is difficult to codify and transfer at a distance, since it is often 'context-specific' and based on first-hand experiences (Gertler, 2003; Bercovitz and Feldmann, 2006; Asheim and Isaksen, 2002; Sunley, 2008). Additionally, geographic proximity increases the chance of "unexpected and spontaneous encounters" occurring (Bathelt and Turi, 2011:525). As argued by one of the research participants:

> "*It's about bringing people together. The best conversations I've had in Harwell have been in the coffee shop*" (Mi.DataApplications2).

These chance encounters are particularly valuable to start-up companies without "*ties to anywhere else"* (S.SystemsManufacturer1b). These networks also lead to "increasing return effects" (Isaksen, 2014:2). For example, firms benefit from: knowledge spillovers, shared infrastructure costs, development of skills in the labour force and transaction efficiency (Malmberg and Maskell, 2002). Consequently, for the twenty-three companies based in Harwell, their location is "*an important part*" of their networking routine (S.SystemsManufacturer1a). To Mi.DataApplications1 there "*is an energy there* [in Harwell] *that is difficult to quantify*".

It is important however, not to overemphasise the role that Harwell plays and underestimate the contribution of external or extra-local connections (Bunnell and Coe, 2001). For instance, distant relations can be maintained by "e-mail, Skype and video-conferencing", which can "cross time zones" and permit the transfer of codified knowledge (Bathelt and Turi, 2011:526). Furthermore, the location of the Harwell site is perceived to be "*mutually inconvenient*" by members of the *space* sector (GovFacilitator1c; German, 2014). This makes it inaccessible for companies based outside of Harwell to benefit from the networking opportunities. This is significant as there are only twenty private companies based in Harwell, thus the cluster accounts for only a small proportion of the networks formed in the UK *space* sector.

Another opportunity for firms to form networks is if they are involved in ESA or European Commission-led projects. These projects facilitate multinational collaboration, as they encourage the sharing of expertise through involving a range of firms from across Europe (Chapter 5, Section 5.4.2). Similarly, the Satellite Applications Catapult Centre, Innovate UK and UK Space Agency take actions to facilitate the "development of linkages between firms" in the sector (Raco, 1999:959) (Section 5.7.3). These examples again highlight the interaction between governance and competitiveness.

Other networks are formed when the firms' representatives attend conferences or "professional get-togethers" that are relevant to the industry (Henn and Bathelt, 2015:105). Conferences vary in purpose, length and participant composition, but generally serve as platforms for exchanging knowledge, generating ideas and forming new relationships (Andersen and Wahlgren, 2015; Weick, 2001; Maskell, 2014). Henn and Bathelt (2015:105) argue that conferences are a "specific type of temporary cluster bringing together knowing communities from cross-industry, functional fields". The bringing together of industry actors and encouragement of face-to-face interactions between them, supports the formation of new networks and strengthens existing ties. To S.DataApplications2, conferences are "*hugely productive for the development of business*" because you can often always find "*an interesting group of people in the room*". The number and variety of delegates who attend means there are often unexpected outcomes from conferences, as well as the achievement of strategic goals. For example, random networks will form from brief discussions over lunch or chance meetings in hallways (Henn and Bathelt, 2015; Billing, 2013).

However, "*people make relationships with people rather than the company*" (L.Prime1a). Therefore, forming networks is largely dependent on whether the firms' representatives are "approachable" and "good face-to-face" (Billing, 2013:47). Additionally, "*conferences are not cheap*" (GovPolicy3c). Consequently, smaller, resource-constrained firms struggle to attend (Aldrich and Auster, 1986). They instead have to rely on virtual networking opportunities. For example, LinkedIn is very popular amongst the satellite community.

Similarly, the ‘Knowledge Transfer Network’ (KTN) site and ‘UK *Space* Directory’ are virtual tools used for networking. The KTN is funded by Innovate UK and “posts relevant articles and advertises upcoming networking events” (Billing, 2013:48). Meanwhile, the UK *Space* Directory is an online portal where firms can access the contact details of others in the industry.

7.5.3 Section Overview: Networks as a Source of Competitiveness

This section investigated the networking routines of UK satellite companies. Networks are valuable to UK satellite companies because they lead to “increasing return affects” (Isaksen, 2014:2), as they widen the resource base of firms (Ellis, 2010; Hervas-Oliver and Albors-Garrigos, 2009). For example, networks facilitate access to capital, which is the focus of the next section. This evidence of the resource bases of firms being shaped by their routines (in this case, networking), highlights the overlap between the RBV and evolutionary perspective (Frenken and Boschma, 2007). This overlap is significant as it supports the decision taken in this chapter to blend theory from two sets of literature.

The section also highlighted the difficulty in distinguishing between strategic and randomly formed networks, since even when a firm strategically seeks-out networking opportunities there may be unexpected outcomes. This cross-over between strategic and random networks, shown through examples of network formation in the Harwell *space* cluster and at conferences, was a new contribution to the literature (Henn and Bathelt, 2015; Anderson and Wahlgren, 2015). The section also identified the interaction between governance and competitiveness, since facilitative forms of governance assist with network formation.

7.6 Managing Access to Capital

Innovation and networking contribute to the competitiveness of the UK *space* sector. However, they are dependent upon the allocation of sufficient financial resources (Mahagaonkar, 2009; Sokol, 2013; Schumpeter, 1939). As Sayer (2001:699) observes:

> "However good the networking, however strong the reliance on information, economic survival for capitalist firms depends on costs and cash."

Therefore, managing access to capital is a routine which also warrants detailed analysis, since it is critical to the growth and competitiveness of start-up and existing UK satellite companies (Pollard, 2003; Pike and Pollard, 2010; La Rocca *et al.*, 2011; Christensen and Hain, 2013). There are three key forms of capital that are "uneven and uncertain" in their supply (Pollard, 2003:436), namely: (i) funding (revenue); (ii) investment capital (external finance); and (iii) government grants. This section explores how capital is accessed and the relative importance of each form of capital to UK satellite companies. The inclusion of grants is significant, since the economic geography literature has previously overlooked their importance when focussing on investment finance (see Clark, 2002; Pollard, 2003; Dixon, 2011b; Wray, 2011; Wójcik, 2011; Sokol, 2013; Coe *et al.,* 2014).

Industry specific features determine the financial needs of firms and their ability to access different forms of capital (La Rocca *et al.,* 2011:108). In light of the fact the manufacturing, operating and applications segments of the UK *space* sector are so different, it is appropriate to separate the analysis of them in this section. Nevertheless, their access to capital is explicitly linked, since funds are transferred between them through their buyer-supplier relationships (Coe *et al.,* 2014).

7.6.1 UK Satellite Manufacturers' Access to Capital

A significant portion of the balance sheet of UK prime satellite manufacturers is accounted for by internal revenue streams generated through the sale of satellites. By way of example:

> "*…although the volumes are low the value of those orders is high; just in the UK, we turnover more than £1bn per annum*" (L.Prime1c).

The cost of a satellite is "*paid for* [by the customer] *at a series of milestones, over the lifetime of the build*" and the price is proportionate to the customer's needs (size and type of payload required) (L.Prime2b; Teece, 2010). The profits from the primes' revenue streams cover their production and expenditure related to sunk costs and innovations. Sunk costs are "committed to a particular use, and therefore are not recoverable in case of exit'" (Clark and Wrigley, 1995:205). One example of a sunk cost is cleanroom infrastructure (Chapter 4, Section 4.2.2).

However, there are "*low orders*" and "*low margins for satellite manufacturers"* selling in mature commercial markets (such as telecoms) (L.Prime1d). Consequently, "*institutional customers* [governments] *and also military customers*" are relied upon by the manufacturers to cover additional costs, such as "*technology development*" (L.Prime1d; L.Prime2b). Institutional and military contracts are less frequent than commercial ones, but more valuable to a manufacturer because the customers are more "*willing to pay for a high cost satellite*" to meet their more bespoke needs (L.Prime1d; GovFacilitator1b). These contracts increase the profits of the manufacturers and demonstrate how governance impacts on the competitiveness of the UK *space* sector, through public contracts "*effectively subsidising*" R&D (GovFacilitator1b). This subsidised R&D increases the likelihood of there being a break with heritage and the introduction of radical changes to production. Therefore, an important part of manufacturers managing their access to capital is them making sure they bid for non-commercial contracts, alongside their commercial ones. They also manufacture other products (such as military aircraft and security systems) that target other industries and user needs (Billing, 2013). This diversification maximises market opportunities and sustains revenue streams (Chapter 4, Section 4.2.2).

Additionally, UK primes depend on European funding (Todd, 1992). For example, manufacturers bid to be involved with civilian satellite projects funded by the European *Space* Programme (Chapter 5, Section 5.4.2). These projects provide greater opportunities for R&D, compared to commercial missions, which have stricter production schedules:

> *"There is pressure to provide transponder bandwidth immediately; they don't want you to play round and experiment*" (L.Prime2c).

Any newly developed "*technological principles*" from the European projects can then be fed back into commercial production (L.Prime1b). The manufacturers are often partnered with an operator on these projects, highlighting the overlap with their access to capital. This is also evidence of how innovation (by manufacturers and operators) is facilitated by access to government funding, highlighting the relationship between public governance and competitiveness.

However, the procurement rules of European funded projects (specifically by ESA) can be restrictive and negatively impact on the competitiveness of UK component manufacturers (Chapter 5, Section 5.4.2). Additionally, "there necessarily are 'losers' as well as 'winners' with European funding (Hudson, 2009:501). Therefore, UK government grants are an important, additional source of capital for satellite manufacturers. Government grants are a facilitative form of governance which is justified on the basis of expected rates of return from "future tax payments" (Hanson and Rohlin, 2011:427; Salamon, 1977). These payments come from taxing satellite services and also taxing employees. Examples of government grants include funding for "*emerging technologies*", through Innovate UK and the Satellite Applications Centre (GovFacilitator1c) (Section 5.4.3). This enables firms to develop in ways which they otherwise could not because of "*limited*" financial resources (M.Applications1b). As argued by Wallsten (2000:82):

> "Government programmes that subsidize commercial R&D are justified on the grounds that profit maximising firms underinvest in R&D."

Additionally, government grant avoids the pressure "*for a very high return on investment*", which is a typical expectation of debt finance through banks (S.SystemsManufacturer1a).

Nevertheless, government grants are not always viewed favourably. For instance, the grant applications are often "*heavily bureaucratic*" and smaller, more resource-constrained firms can struggle to manage the workload required for the process (M.Prime2a; Billing, 2013). Additionally, an over-reliance on government grants has the potential to create an "*artificial funding mechanism*" that is vulnerable to the impacts of policy change (S.SystemsManufacturer1a). Therefore, it is important for the manufacturers to manage their dependency on this form of capital. Furthermore, there is evidence of the grants replacing private R&D, which has meant technological innovation has remained at a constant level (David *et al*, 2000). Instead, grants need to supplement private R&D and increase overall activity in the industry (Wallsten, 2000). To achieve this it is important for a government to not necessarily "fund the best proposals they receive", but instead fund the best proposals from those who are unlikely "to receive adequate funding from other sources" (Wallsten, 2000:84).

The next section provides a comparison to the financial resources of UK satellite manufacturers, by instead focussing on the access to capital by UK satellite operators.

7.6.2 UK Satellite Operators' Access to Capital

The cost of a satellite is so high- "*about $500 million each*"- that if an operator wants to launch a new service "*to meet customers' needs*" it has to access a significant amount of capital (S.DataApplications1; L.Operator1a). Without sufficient access to capital, an operator will not be able to finance the manufacturing of their satellite or pass the credit-check phase of the *space* licensing process (Chapter 5, Section 5.6.1). As the most profitable of the three industry sectors, revenue streams are a significant contributor to the financial resources required by UK satellite operators. By way of example:

> "*Capacity at 28 degrees east is like 200 transponders, each one of those would pay roughly £3 million* [per year], *so you can do your sums and figure out that this is a profitable business, if you can get a 70% occupancy*" (L.DTHApplications2).

Although operators' margins are significant, the "*high capital investment cycles*" required to launch new services cannot be sustained by only existing profits (GovFacilitator2c). Therefore, operators also try and "*pre-sell capacity on a satellite before they launch it*" (L.Operator1b; S.Operator1b; S.Operator3c). Under these pre-sale agreements, operators prefer customers to commit to a long-term contract, which would cover the lifetime of the satellite (typically 15 years). Nevertheless, service providers typically opt for "*one to five year contracts*" (L.DTHApplications1). This is a more expensive option (long-term contracts carry a greater discount), but affords the service provider greater flexibility to adapt to "*other opportunities or needs as they come along*" (L.DTHApplications1). Therefore, pre-sale agreements cannot be relied upon to cover the cost of a new satellite.

Operators can at least try and offset some of their costs by having a 'hosted payload' on another operator's satellite. This option is a lot cheaper for both operators, since they can "*share the costs*" (L.VSATApplications1). However, it limits their service capacity and means that the operator who is not the host can have less input in the satellite's design. Therefore, hosted payloads are not always a feasible option for offsetting costs.

Consequently, UK satellite operators have to rely on accessing debt and equity finance as a financial resource. This is particularly true for younger operators, who cannot rely on existing revenue streams. For instance:

> "*We are basically funded by 60% debt and 40% equity… So our debt is headed up by HSBC and under it we have I forget how many banks, it's about 14 different banks coming under it, including a whole load of development banks as well and a consortium of development banks*" (S.Operator2b).

Proximity to the city of London helps the operators to access this finance, as it is one of the largest global financial centres and stock markets (Sokol, 2013; Wójcik, 2009; Amini *et al.*, 2010):

> "*Our proximity to the city of London helps; there is a lot of investing in satellites through London, at the large scale*" (M.Operator1b).

This example is consistent with the economic geography literature, which has documented the impact of variegated financial landscapes on access to capital (Martian, 1999; Sassen, 2001; Clark, 2002; Clark and Wojcik, 2007; La Rocca *et al.*, 2011; Hall, 2012).

Operators increase the likelihood of obtaining external finance by signalling reliability to investors (Spence, 1974; La Rocca *et al.,* 2011). They achieve this by advertising their heritage and minimising the perceived risk of their *space* activities. In this case, heritage relates to wider investment performance or "record of profitability" (La Rocca *et al.*, 2011:111; Spence, 1974; Mazzucato, 2013; Lee and Brown, 2016). They minimise risk by avoiding radical innovation, as to investors, innovation is "a speculative process" which may disrupt debt repayment or equity stakes (Freel, 2007, 23). Therefore, operators find that "*incremental innovations are easier to fund*" (S.GovResearch1). This highlights the relationship between innovation and access to capital, whilst also reinforcing the importance of heritage in the industry. Younger firms however, do not have the requisite heritage to signal reliability to banks. They rely more on equity finance and its associated 'patient capital', with which investors are better prepared than banks to "*wait for long-term economic returns on investments*" (La Rocca *et al.*, 2011:111). Typically, "a higher number of patent applications" would increase the likelihood of accessing equity finance, thus encouraging innovation (Audretsch *et al*., 2012:1407). However, young operators are subject to the same insurance and licensing regulations as the rest of the industry, meaning they too are relatively conservative in their approach to innovation. This is another example of how heritage and governance impact on innovation routines. The operator's routines then impact on innovation in the satellite application sub-sector, which is explored in Section 7.6.3.

7.6.3 UK Satellite Application Providers' Access to Capital

This sub-section explores access to capital by UK satellite applications providers. The specific focus is on value-added service providers (using EO data), as unlike satellite manufacturers and operators they are not as capital intensive as other parts of the *space* industry and part of a newly, emerging sector. A brief outline of direct-to-home (DTH) providers and their access to capital is also given for comparative purposes. However, it is beyond the scope of this thesis to discuss the financial and funding model of a television broadcaster.

Similar to satellite operators (although not to the same degree), DTH providers have high infrastructure costs, as they have to lease their transponder capacity from operators. Nevertheless, they are able to cover these costs with their profits from customer contracts, thus avoiding the need for external finance. In fact, for DTH providers covering the costs relating to their satellite infrastructure is only a small part of their business:

> "…*you may have seen in the news how much money we spent buying football rights recently. The transponder costs a small beer quite frankly compared with the totality*" (L.DTHApplications2).

In contrast, value-added service providers are a lot less capital intensive, as they find that "*computer power is cheap*" and their "*biggest cost is people*" (S.DataApplications2). The EO data they use can also be expensive, "*depending on the level of resolution*", but they are increasingly finding that "*free datasets are being made available*" (M.DataApplications1c; Mi.DataApplications3). The majority of satellite application companies however, are small start-up firms. Therefore, their cash flow is limited and they rely on external finance and government grants. For example, 'innovation vouchers' are government grants of up to £5000, awarded by Innovate UK (Chapter 5, Section 5.7.3). By way of example:

> "*We received funding through a European scheme. And then otherwise not through direct support but grants operated by the research councils, by the Royal Society, Innovate UK, they have been significant providers of relatively speaking soft funds*" (S.DataApplications2).

This again highlights the relationship between public governance and the competitiveness of UK satellite firms. As with the manufacturers however, smaller data companies can sometimes struggle with the bureaucracy of some of these funding opportunities. It is also difficult for them to access debt finance because without heritage (investment performance or record of profitability), it is not easy for them to signal reliability to investors. Consequently, application providers rely on venture capitalists and business angels. Venture capitalists provide 'patient capital' and are particularly valuable because they often provide a firm with extra business advice and support (Wray, 2011; Hellmann and Puri, 2000).

Business angels are even more 'hands on' in their approach than venture capitalist because they have previously worked in the industry (Giudici and Paleari, 2000: Mason and Harrison, 2000). This is the case for business angels involved in any industry and means they have an interest for the sector that encourages them to invest in high-risk projects when other investors would not. It also means they have specialist knowledge on the industry, which they can pass onto firms (Johnson and Sohl, 2012). These business angels are accessed through formal networks, some of which are focussed entirely on *space* ventures. For example, Seraphim Space Fund is a £83million venture fund that was set up in 2016 to fund six start-up companies, every financial quarter. Similarly, the 'Space Angel Network' was launched in the UK in 2014 and is "a global organisation that helps connect *space* entrepreneurs with angel investors" (Billing, 2013:46). The Seraphim Space Fund and Space Angel Network are examples of "entry points that venture capitalists have to investor networks", which "little is known about" in the literature (Wray, 2011:298). It challenges the significance of the "uneven geography of equity finance" (Lee and Brown, 2016:2), since although venture capitalists and business angels are not evenly distributed across space these networks mean they can still be accessed (Hall, 2013; Dixon, 2011b). For example:

> "*If you take the last million we raised, we raised £200,000 from our current shareholders, £300,000 from a couple of* [business Angels] *from the US, £500,000 from some Russians. So the UK provided very little*" (S.DataApplications2).

The above example is evidence of how the UK is not "*big on investment because of being risk averse*", which contrasts to "*Silicon Valley where you can get $200 million just like that*" (M.Prime2a). However providing firms manage their networks and innovation, they can minimise uncertainty and access venture capital from anywhere (Mason, 2007).

7.6.4 Section Overview: Access to Capital as a Source of Competitiveness

This section has highlighted the impact that industry specific features have in determining the financial needs of firms and their ability to access different forms of capital (La Rocca *et al.*, 2011:108). Capital is not identified in the RBV as an internal resource but is necessary to unlock access to other intangible competitive advantages, such as innovation (Barney, 1991; Peteraf, 1993). For example, the satellite manufacturing sector has low-profit margins (2-8% EBIT margin) and is therefore reliant on institutional contracts and government grants. This focus on grants highlights its importance along with other types of investment capital. In contrast, satellite operators are less dependent on grants and have significantly higher margins (30-40% EBIT margin). However, their high capital investment costs require them to access external finance. They are able to access debt and equity finance by signalling reliability to their investors. Finally, value-added service providers are not capital intensive but struggle to access debt finance and government grants. They therefore rely on a network of venture capitalists, which they can access from anywhere. This demonstrates the overlap between networking and access to capital.

This section also highlighted how investment performance or record of profitability contributes to a firm' heritage and how, without it, it is difficult for firms to signal competence-based trust to stakeholders (La Rocca *et al*., 2011; Kennedy *et al*., 2001). This aligns with the evolutionary perspective on how existing assets impacts on future firm behaviour (Frenken and Boschma, 2007; Martin and Sunley, 2006). The next section brings together the findings from this and the previous sections to provide an overview of firm-level competitiveness in the UK *space* sector.

7.7. Conclusion: Explaining Firm-level Competitiveness in the UK *Space* Sector.

In an industry characterised by "*severe competition*" it is important that UK satellite firms find ways to differentiate themselves from their competitors (GovFacilitator2d). They achieve this through five internal resources: (i) orbital slots and frequency spectrum; (ii) heritage; (iii) innovative capability; (iv) networks; and (v) capital. These are all accessed or developed through routines (with the exception of orbital slots/frequency spectrum). The approach taken to understand these sources of competitiveness was to apply theory from both the RBV and evolutionary literature. This section provides an overview of the impact that the resources have on the competitiveness of UK satellite firms.

First, this chapter highlighted the necessity of accessing appropriate orbital slots and frequency spectrum for specific satellite services. This process is undertaken by satellite operators, but manufacturers and application providers rely on its success. A number of routes to accessing orbital slots/frequency spectrum were identified, with acquisitions proving to be particularly popular. Accessing orbital slots/frequency spectrum is not an everyday firm-based routine, since it is a competitive practice that occurs only when an operator needs to launch a new service (Jensen, 2010; Maskell and Malmberg, 2007; Boschma and Frenken, 2006). This distinction between a routine and a competitive practice is important, since the literature has done little to define explicitly what is and is not a routine. The similarities between property, orbital slots and frequency spectrum were also outlined, which furthered the vertical geopolitics debate (Weizman, 2002; Elden, 2013). Additionally, the chapter explored how without satellite infrastructure, launch vehicles and ground stations, the value of orbital slots or frequency spectrum cannot be realised. This highlighted the significance of tangible resources to the competitiveness of the *space* sector and the interdependency between tangible and intangible assets.

Second, this chapter identified heritage as an intangible asset which provides a "*very powerful competitive advantage*" for UK satellite manufacturers and operators (GovFacilitator2d). The heritage is characterised by three key attributes: (i) technical engineering performance of the products; (ii) the firms' experience in the sector (which is partly about the relationships they have formed); and (iii) record of profitability. Heritage differentiates firms by signalling reliability of a firm or product to key stakeholders (including customers, investors and collaborators), which encourages competence based trust (Galbreath, 2005; Mascitelli, 2000; Turban *et al.,* 1998). Competence-based trust is particularly valued in the *space* sector because of the high risks associated with launch and orbit environments. Therefore, heritage offers firms a higher status in the market and leads to accumulative advantage (Billing, 2013; Podolny, 1993). This creates a high barrier to entry and encourages a monopoly of mature operators and manufacturers who dominate the market (Agarwal *et al.,* 2002). It also impacts on the firms' routines. For example, it encourages a conservative approach to innovation. This relationship between innovation and heritage aligns with the evolutionary perspective of how previous actions and decisions "affect the probability" of the future behaviour of firms (Boschma and Frenken, 2006:280). It also highlighted the importance of blending two sets of literature in this chapter, since the evolutionary perspective explains the credit of heritage, whilst the RBV has overlooked it as an intangible resource.

Heritage is so important to UK satellite firms because of the high-risk nature of the industry. These risks are associated with: (i) the extreme launch environment; (ii) the inability to mend a satellite once it is 'up there'; and (iii) the high cost of satellite infrastructure. This is important to highlight as whilst there were conclusions that were consistent with other industry studies on competitiveness, there were also distinctive characteristics that are industry specific such as, the value of flight history. This shows the value in continuing research on industries that have previously been overlooked, since they are likely to further our understanding of firm competitiveness. For instance, economic geographers have previously only explored heritage in relation to retro fashion (Tokatli, 2012; De Vaan *et al.*, 2012).

Third, this chapter explored innovation as a key source of competitiveness (Hall, 1993; Ireland and Webb, 2007). A firm's innovative capability is a product of its innovating routines, which include "co-ordinating technological resources external to the firm" (Pavitt, 2002:119). These competitive practices are routines (i.e. everyday patterns of behaviour), since firms continually innovate their "existing processes and products" (Bryson and Taylor, 2010:586). The analysis of these innovating routines highlighted the different practices and approaches taken by manufacturers, operators and application providers. These differences are a factor of the sector specific features and varying market conditions (Carayannis and Provance, 2008; Jones and Craven, 2011). Differences were also found between companies in the same sector. For example, innovation surrounding Earth observation satellites is less incremental than telecommunications satellites. The influence of heritage on innovation was also highlighted, as heritage encourages manufacturers and operators to be incremental in their approach to innovation. This has led to technological lock-in in the telecommunications sector, which has only been overcome in the Earth observation market because of the significant reductions in price caused by path-changing technologies. These breaks with heritage demonstrate how in some BSRs heritage matters and in others it does not (Chapter 6).

Fourth, networking with universities and other companies was found to support innovation, since it broadens firms' access to resources and maximises their awareness of market opportunities (Pollard, 2003). Some of the intra-firm networks were found to cross sectors (satellite applications, operations and manufacturing), which is evidence of the interdependency between the three segments of the industry. For the twenty three companies based in the Harwell *space* cluster, their location is "*an important part*" of forming these networks (S.SystemsManufacturer1a). There are two sets of routines involved here, namely: (i) networking as a process; and (ii) if a relationships forms, the management of that relationship and other networks of partners. However, the Harwell site serves only a small number of firms that are involved in the UK *space* sector, thus its importance must not be exaggerated. In contrast, conferences have a much broader impact on network formation in the UK *space* sector, such finding being a valuable empirical contribution to the temporary clusters debate (Henn and Bathelt, 2015; Anderson and Wahlgren, 2015). However, conferences may exclude smaller firms, thus virtual networks are also valuable to the industry. Facilitative forms of governance (such as ESA projects) also support network formation, which highlights the interaction between governance and competitiveness.

Fifth, managing access to capital is a firm-based routine which was identified as critical to the growth and competitiveness of start-up and existing UK *space* companies (Pollard, 2003; La Rocca *et al.*, 2011; Christensen and Hain, 2013). It was also found that sector specific features determine the financial needs of firms and their ability to access different forms of capital (La Rocca *et al.*, 2011). Therefore, the financial resources of satellite manufacturers, operators and applications providers are very different. The satellite manufacturing sector was found to have low profit margins and is therefore reliant on government support, through institutional contracts and grants. In contrast, satellite operators are less dependent on government grants and have significantly higher margins. However, their high capital investment costs require them to access external finance. They are able to access debt and equity finance by signalling reliability to their investors. Proximity to the city of London helps the operators to access this capital, as London is one of the largest global financial centres and stock markets (Sokol, 2013; Wójcik, 2009; Amini *et al.*, 2010; Thompson, 1977). Finally, value-added service providers are not capital intensive but struggle to access debt finance and government grants. They instead rely on a network of venture capitalists, which they can access from anywhere.

Whilst the five internal resources were discussed separately in this chapter, they were found to be interdependent (Hölzl, 2005). Interactions between them are identified in Figure 7.2 below. For example, innovation is dependent on networks for accessing sufficient financial resources (Mahagaonkar, 2009; Sokol, 2013; Schumpeter, 1939). Similarly, access to capital is needed for acquisitions and buying orbital slots/frequency spectrum in the orbital market. In contrast, there was found to be a tension between heritage and innovation, as with satellite manufacturing, heritage poses a barrier to disruptive change in the industry. Consequently, UK satellite manufacturers typically make only incremental changes, so as to maintain the heritage of their products.

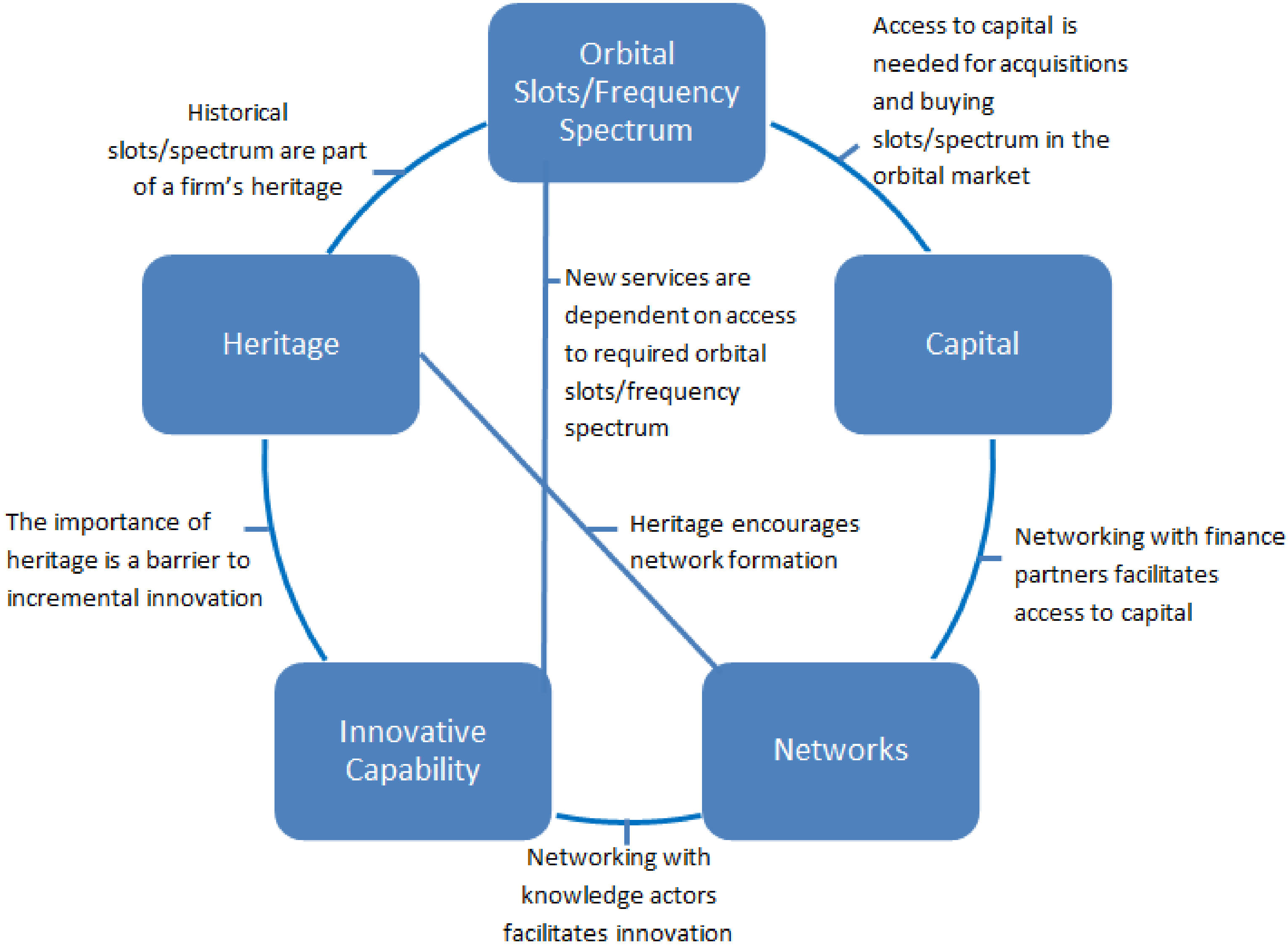


Figure 7.2: A diagram to highlight the interactions between internal resources.

Source: Author.

CHAPTER 8

CONCLUSION: A PLACE FOR *SPACE* IN GEOGRAPHY

8.1 Introduction

There is an ever greater reliance by societies on satellite-enabled applications. Consequently, the importance of the *space* sector to the environment, economy and defence of the UK cannot be overstated. Nevertheless, the economic geography of the satellite industry has been ignored and the 'grounded nature' of the *space* sector has been underplayed. To address this 'silence' in the social science literature, this thesis has explored the competitiveness, organisation and governance of the UK *space* sector. The qualitative approach to the research involved three phases of data collection: (i) desk-based research; (ii) eighty in-depth interviews with participants from across the *space* sector; and (iii) attending relevant *space* events. This data collection was undertaken concurrently, with three stages of analysis to ensure any knowledge gaps were addressed. The adopted design, approach and methods for this study were chosen on the basis that they are practical, whilst maximising the internal validity, external validity and reliability of the research findings.

The research has made two broad contributions. First, it has developed understanding on a critical sector by identifying the sources of competitiveness of the firms involved; the nature and extent of the buyer supplier relationships (BSRs); and the impact of different forms and scales of public and private governance on different stages of production. Second, the research has addressed specific gaps in the economic geography and wider social science literature. These research gaps specifically relate to: (i) firm-level competitiveness; (ii) the distribution of production tasks; (iii) BSRs; (iv) public governance; and (v) private governance. New theoretical contributions have been uncovered because the *space* sector is exposed to distinctive technical challenges and financial risks, meaning that aspects of the research findings on firm-level competitiveness, organisation and governance were distinctive from previous studies. This demonstrates the value in researching sectors which have previously been overlooked. Additionally, research gaps were addressed as a result of the approach taken to simultaneously investigate the competitiveness, organisation and governance of the UK *space* sector. It was necessary to integrate research on competitiveness and organisation because the sector has a complex structure, consisting of three interdependent sub-sectors (i.e. s*pace* manufacturing, satellite operations, and the provision of satellite-enabled applications). Therefore, since the sources of firm-level competitiveness in the *space* sector vary due to the differences between the three groups of firms involved, it was vital to outline the organisation of each of the sub-sectors (i.e. their role, spatial distribution and BSRs) before firm-level competitiveness could be fully understood. Additionally, it was recognised that external factors impact on competitiveness and therefore also warrant consideration (Porter, 1990; Dögl *et al*., 2012). These external factors include various forms of governance emanating from a national, European and global scale. Consequently, research into the governance of the UK *space* sector was also a key part of the thesis.

This concluding chapter identifies the key contributions made by the research by bringing together the findings from the previous chapters. A variant of the conceptual framework of the thesis is also provided, which includes additions which specifically relate to the research findings. The chapter also identifies what lessons can be taken from this thesis by industry and policy makers, as well as opportunities for further research. The first section outlines the key findings on the governance of the UK *space* sector. This is separate from the discussion on organisation (Section 8.3) and competitiveness (Section 8.4); however, the three areas interrelate, and so any overlaps between them are also identified.

8.2 Governance of the UK *Space* Sector

It was important to explore governance in this thesis, since understanding the *space* sector is largely about understanding its complex regulatory framework and its reliance on government support. The focus was on identifying the impact of national and supranational forms of public and private governance on different stages of UK satellite production projects. A polycentric approach framed the discussion in order to account for the multi-scalar actors involved and the analysis was divided between five key processes which precede the delivery to market of a satellite application (Coen and Thatcher, 2008; Kooiman, 2000). The forms and scale of governance were found to vary between the five processes, as shown below in the summary of each of them.

Allocation of an Orbital slot and Frequency Spectrum

The governance of the allocation of orbital slots and frequency spectrum is regulatory and is enforced on both a global and national scale (Venet, 2012:60). The relationship between the two scales of governance is non-hierarchical, as the global actor, the International Telecommunications Union (ITU), behaves more as a gateway rather than a gatekeeper. This is reflected in the limited power the ITU has over satellite operators. For example, the ITU does not have the authority to financially penalise operators for reserving orbital slots and frequency spectrum without intention for their actual use. Meanwhile, nation states, through Independent Regulatory Authorities (IRAs), are responsible for allocating slots and spectrum on behalf of the ITU and enforcing ITU protocols. This counters the argument in the literature that "national policy instruments" (Ansell, 2000:306) have been "eroded by supranational powers" (Mclaughlin and Maloney, 1999:1). IRAs differ in "age, power, autonomy, finance and staffing" (Coen and Thatcher, 2008:55) and thus vary in the degree to which they enforce ITU protocols. These differences have led to jurisdiction selection, as operators choose to locate their headquarters in countries which regulate in a favourable way. One operator may prefer a country with a "well-functioning legal" system where ITU protocols are strictly enforced (Clark and Monk, 2014:11), whereas another may prefer somewhere where there are less stringent regulations. This can work for or against UK foreign direct investment, as some operators find the UK too '*strict'*, while others are attracted to its reputation of '*doing things right*'. Access to orbital slots and frequency spectrum is important to UK satellite firms because they are finite resources, and thus they provide a key source of competitiveness.

Satellite Procurement

The procurement of civilian satellites is framed by legal norms emanating from both the European and national level. Governance at the European level involves procurement rules set by the European Space Agency (ESA) and the European Commission. These rules apply to European projects, which UK satellite firms are motivated to be involved with because they: (i) facilitate collaboration between different countries; and (ii) encourage breaks with heritage through the development of new technology. ESA's procurement rule (*juste retour*) has the greatest influence over procurement in European projects because ESA projects are more common than those led by the European Commission. The *juste retour* principle (ESA procurement rule) places significant restrictions on the organisation of production, since unlike in commercial projects, manufacturers are not free to choose their suppliers. This is an example of how a facilitative form of governance (procurement opportunities) can also be a regulatory form, highlighting the difficulty in separating the two. European member states (including the UK) do retain some degree of control, as they set ESA's budget and select which optional programmes to subscribe to. They also impose their own procurement rules through trade regulations, which are as influential as those at the European level because, unlike ESA's procurement rules, they apply to commercial and military projects.

Satellite Insurance

Satellite insurance is "designed for protecting against the financial consequences of events occurring between lift-off of the satellite and its end life" (Montpert, 2011:238). Private companies play a crucial role in issuing this insurance, which helps manufacturers and operators protect themselves against risk. There are two types of satellite insurance: (i) damage insurance; and (ii) liability insurance. Damage insurance is "designed to protect operators against the physical loss of the reduction in performance of a satellite" (Manikowski and Weiss, 2013:177). The cost of a damage insurance policy is impacted by the type of launch vehicle, the financial stability of the operator, and the heritage of the satellite design (i.e. flight history of the components and the experience of the manufacturer). Therefore, it impacts on the organisation of production, since it influences the selection of suppliers by both operators and manufacturers. Liability insurance protects the satellite operator and the launching state "against the financial consequences of damages caused to a third party" (Montpert, 2001:283). The compulsory limit for liability insurance in the UK is set at €60 million, which is enforced by private insurers (Bennett, 2000:887). The dual role played by non-state actors and the government in this regulatory process furthers the political-economic argument that governance is neither public nor private (Bartley 2007; Black, 2001; Grabosky, 2013; Bennet, 2000).

Obtaining a *Space* Licence

The *space* licensing process is also a form of regulatory governance, which is managed by national governments, but based on the supranational principles of the Outer *Space* Treaty. Satellite licences also vary between national contexts, influencing the location decisions made by operators and highlighting the continued importance of place (Neilson and Pritchard, 2009). The key premise behind the *space* licence process is to prevent excessive risk and thus, like the insurance process, it affects the “diffusion of new technologies” (Gruber and Verboven, 2011:1190). For instance, one stage of the licensing process is a ‘technical check’, which favours satellite designs that involve ‘proven’ components with heritage.

The delivery of Satellite-Enabled Applications

The UK government, the European Commission and ESA play a joint role in facilitating the delivery of UK satellite-enabled applications, through grants, procurement and supporting network formation. Private actors (i.e. large satellite firms) are also involved, as they influence policy action through consultation with the UK Space Agency. Therefore, a multi-level governance system impacts on this process, involving private, national and supranational actors. The facilitative forms of governance are important as they assist firms in accessing resources which provide a source of competitiveness. Regulatory forms of governance also impact on the delivery process. For example, landing rights must be obtained from every national site to which a telecommunications operator hopes to send signals to. Consequently, there is evidence of “de-statization” and a dual-effort (between different nation states) in regulating the sector (Dixon, 2011:194).

Overall Governance of the UK *Space* Sector

Overall, there was found to be an absence of "a single identifiable centre of authority" governing the UK *space* sector (Mazurelle *et al*, 2009:161), since decision making is diffused between various actors across a global, European and national level (Bulkeley and Betsill, 2005:36; Lobel, 2012; Zielonka, 2007). Additionally, there is a dominance of regulatory forms of governance over facilitative forms of governance. This is significant, as whilst facilitative governance focusses on the promotion of economic activity, regulatory governance imposes limits on the "scope of private activities" (Mayer and Pickles, 2010:2; Cheng, 2015:382). Consequently, the impact of governance on the industry is more restrictive than enabling. This distinction between facilitative and regulatory governance is important, but nevertheless absent from other industry studies (see Bailey and Maresh, 2009; Bennett, 2000; Eling, and Marek, 2014; Griffin, 2008; and McLaughlin and Maloney, 1999).

Furthermore, the nation state plays a central role in all five processes, by enforcing regulations and facilitating market growth, whilst EU procurement rules and supranational treaties set the "the ground rules" for governance and regulatory order (Jessop, 2011:119). This highlights the importance of UK government involvement to the competitive success of the UK satellite industry, whilst emphasising the need for it to engage and cooperate with supranational and other national stakeholders. This explicit theorisation of the role of the nation state is significant, since it is something which has been lacking in the global production research (Neilson *et al*, 2014; Smith, 2015). Furthermore, it counters Nadvi's (2008:331) argument of how global scales of governance are "increasingly undermining the regulatory powers of national governance".

8.3 Organisation of the UK *Space* Sector

Understanding the UK *space* sector's 'industrial governance' is also important in characterising its economic geography; it is part of the organisation of production and concerns the relationships between buyers and suppliers in production projects (Gereffi and Mayer, 2006; Nadvi, 2008; Bair and Palpacuer, 2015). The starting point for exploring the sector's industrial governance was to first identify the role and spatial configurations of the various agents involved. It identified that the UK *space* sector divides into three segments or sub-sectors, namely: (i) s*pace* manufacturing; (ii) satellite operations; and (iii) the provision of satellite-enabled applications. These sub-sectors all manage their own production projects and tasks, but are interdependent. This means that developments and challenges in one, creates opportunities and barriers in another (Smith, 1776; Harvey, 2014; Neilson *et al*., 2014). The role and geography of these sub-sectors are summarised in Table 8.1.

Table 8.1: UK *Space* Sub-Sectors: Roles and Geography.

Sub-Sector	Role	Geography
Satellite Manufacturing	Manufacturing and integrating the components of a satellite.	There are a small number of large primes (which manage the final assembly of satellites) in the market, four of which are based in Europe and only one which assembles satellites in the UK (Qi3, 2012). The primes' supply chain of components is global, with their production networks dispersed across the US, Europe, Russia, Japan and India. However, where possible they tend to buy locally in Europe, since trade regulations complicate buying from countries outside Europe.
Satellite Operations	Financing the construction and launch of a satellite and selling communication bandwidth, positioning signals or Earth-observation data.	There is a precise geography to the office locations of satellite operators, since they are often within close proximity to market-hubs, which correspond to their satellites' footprints. UK based operators have offices in London because, traditionally, it was important to be near to the BT tower. This is an example of path-dependency caused by sunk costs (Clark and Wrigley, 1995; Martin and Sunley, 2006). Furthermore, operators' location decisions are influenced by proximity to satellite application providers, who purchase data and bandwidth from them.
Satellite Applications	Distributing television signals to small dishes and satellite receivers or adding value to raw observation data and transforming that data into a usable information service.	Direct-to-home (DTH) providers are also restricted to market hub locations. However, in contrast to their operating counterparts, value-added service providers can access data from almost anywhere and so otherwise are not geographically restricted.

Source: Author.

As part of exploring the spatial configurations of the industry, the geography of satellite Earth stations and launch sites was also investigated. They were found to be spatially influenced by the geographic advantages of particular locations. For example, an Earth station must be positioned along the ground track of the relevant orbit intended for a mission. Similarly, launch sites are chosen based on their relative position (latitude) to the height and inclination of primary orbits. These research findings highlight that first-nature geography remains an important location factor in the *space* sector, unlike in many other industries (Krugman, 1993; Dupuy *et al*, 2010; Sheldon, 2014). First nature geography comprises of the natural advantages presented by a location, particularly in respect of its resources and geographical position (Krugman, 1993; Fujita and Mori, 2005; Zubarevich, 2009).

To conceptualise the structure and character of buyer-supplier relationships (BSRs) in the UK satellite industry, the Global Value Chain (GVC) governance typology was applied (Gereffi *et al*., 2005; Sturgeon, 2001; Henderson *et al.*, 2002). The following adjustments were made to the typology to address criticisms and account for industry specific features: (i) focussing on more than a single procurement moment; (ii) distinguishing between captive-buyers and captive-suppliers; (iii) prioritising the ‘degree of coordination’ and ‘power asymmetry’ as BSRs variables over the ability to ‘codify information’ and ‘supplier capability’; and (iv) the consideration of external governance factors. The analysis was divided between the BSRs involved with the sale of satellites and those involved with satellite-enabled applications, to account for differences between production projects and the firms involved.

Vertical integration and upgrading of key production projects were found to be uncommon in the UK *space* sector (i.e. a single firm both manufacturing and operating a satellite). Consequently, there is a separation between satellite manufacturing, satellite operating and application provision in the UK *space* sector. This is due to the differences between the projects (such as the speed of production, labour intensity and profit margins), which create obstacles to vertical integration and upgrading.

An operator chooses a satellite manufacturer on the basis of price, availability and if an ESA project, *juste retour*. External governance factors also have an impact (Gibbon *et al.*, 2008; Rainnie *et al.*, 2011). For example, the insurance and *space* licensing process encourage satellite designs with heritage, which has an influence upon which manufacturer an operator chooses. The exchange of the satellite between the manufacturer and operator is characteristic of a relational type BSR, since the complexity of the product warrants the exchange of knowledge and ideas between the manufacturer and operator (typical of a relational type BSR). However, the exchange of institutional projects is also characteristic of a captive-buyer type BSR, as ESA procurement rules create a concentrated market of satellite manufacturers. Similarly, fierce competition in the commercial satellite manufacturing market limits the procurement opportunities and makes manufacturers transactionally dependent on operators (captive-suppliers). Therefore, the BSR type governing the sale of a satellite is both captive and relational (captive-relational). This recognition of the crossover between captive and relational type BSRs contradicts other "relational content-based typologies", which have suggested that "power-dependence becomes irrelevant in a highly relational BSR" (Tangpong *et al*., 2008:575). It also demonstrates that "power is fluid" and its distribution can change over time (Tokatli, 2007). For example, a longer-term relationship between a manufacturer and an operator can facilitate the development of trust, as well as encouraging interdependency. The existence of trust and interdependency creates a more even power distribution.

Similarly, there is not a single BSR type which governs the sale of UK satellite-enabled applications, as the applicable type varies depending on the buyer (i.e. end-user, service providers, market resellers or other operators); contract (i.e. varying lengths and service level agreements); and satellite function (i.e. telecommunications or Earth observation).

For instance, in the telecommunications market, there are only a small number of operators due to the limited availability of geostationary orbital slots. This constraint causes the buyers (specifically direct-to-home 'DTH' providers) to be transactionally dependent on the operators, which results in a captive-buyer type BSR. Suppliers in this relationship are chosen on the basis of footprint, sunk costs and competence-based trust (i.e. their heritage). However, this is not applicable to all telecoms buyers, as resellers have a more fluid relationship with operators and modular type exchanges exist (Gereffi *et al*., 2005). Similarly, 'Very Small Aperture Terminals' (VSAT) operators have greater flexibility, as they are not locked into fixed antennae. With Earth observation applications, the nature and structure of the BSRs are closer to a market form of industrial governance, as the exchanges are more standardised and there is also no lock-in.

Overall, the analysis highlighted how, depending on the type of satellite (telecommunications or Earth observation) and the buyer involved (commercial or institutional), the most powerful actors in each BSR will vary. The recognition of these distinctions is important because the literature has previously only identified how "linkages typically differ between different segments of the value chain" and not how they can differ between different products in the same industry (Ponte and Sturgeon, 2014:206). The differences between each BSR type are accounted for by the different technologies involved. Technology has previously been ignored as a factor impacting BSRs in the GVC governance literature because, apart from electronics, the typology was based on low-tech industries (for example, bicycle, apparel, horticultural industries) (Gereffi *et al*., 2005).

8.4 The Competitiveness of UK Satellite Firms

Outlining the governance and organisation of production in the UK *space* sector was a core factor in identifying the sources of competitiveness for UK satellite companies. The research also identified the internal resources that are a key source of competitiveness for UK satellite companies, whist highlighting the routines which develop and access those resources. Focussing on these aspects of firm-level competitiveness emerged from a theoretical approach which blended the resource-based view (RBV) and evolutionary perspective (Barney, 1991; De Rassenfosse, 2012; Dubois, 2015; Walsh and Beatty, 2007; Bryson and Ronayne, 2014; Phelps and Fuller, 2016). The internal resources include: (i) orbital slots and frequency spectrum; (ii) heritage; (iii) innovative capability; (iv) networks; and (v) capital. These resources interrelate and can complement one another. For example, innovation depends on networks providing access to sufficient financial resources (Mahagaonkar, 2009; Sokol, 2013; Schumpeter, 1939). The significance of each internal resource, and how they are accessed or developed through routines, is outlined below.

Orbital Slots and Frequency Spectrum

The provision of satellite-enabled applications is dependent on access to relevant orbital slots (if a fixed satellite service) and frequency spectrum. This directly relates to UK satellite operators, since they are the agents who ‘own’ the rights to orbital slots and frequency spectrum. Nevertheless, manufacturers and application providers are indirectly dependent on the operators accessing slots and spectrum, in being able to obtain contracts and provide services respectively. The ability to access orbital slots and frequency spectrum provides a source of competitiveness because, whilst *space* is a vast area, useful slots and spectrum are finite resources. Consequently, there is a first-mover advantage

(FMA), whereby operators who apply first for slots and spectrum can potentially thwart "other firms' attempts to compete" (Finney *et al.*, 2008). This challenges Collis' (2009) argument that the GEO orbit is a contested space, since the slots are controlled by those who get there first. There are a number of different routes to accessing orbital slots and frequency spectrum, including: (i) the formal process; (ii) leasing capacity; (iii) buying and exchanging on the orbital market; and (iv) acquiring other operators. Acquisitions of other operators prove to be most popular. These routes to accessing orbital slots and frequency spectrum is not an everyday firm-based routine, since they occur only when an operator needs to launch a new service (i.e. every five years) (Jensen, 2010; Maskell and Malmberg, 2007; Boschma and Frenken, 2006).

An operator's ability to use its allocated orbital slots and frequency spectrum is dependent on a launch provider successfully delivering the satellite(s) to the appropriate orbit and position, as well as it having access to ground stations. This highlights the significance of tangible resources to the competitiveness of the UK *space* sector. This contradicts the RBV debate, which argues that tangible resources are a "relatively poor source of advantage" (Fahy, 2002:64). In practice, tangible assets (such as ground stations) support intangible assets (such as orbital slots/frequency spectrum) and the two cannot be separated. Furthermore, the use and exchange value of orbital slots and frequency spectrum mean they share similarities with property on Earth. This link contributes to the vertical geopolitics work, which explores the "height and depth" of territories (Weizman, 2002:3; Elden, 2013:49).

Heritage

Heritage has two forms: (i) the heritage of a firm (including its relationships); and (ii) the heritage of individual products. It impacts mainly on satellite manufacturers and satellite operators, since heritage is more relevant to the sale of a satellite, compared to other stages of production in the sector (Chapter 6). Nevertheless, service providers (particularly DTH providers) are under pressure to choose reliable operators to supply them with bandwidth/data for delivering a good service to their customers (L.DTHApplications1). Therefore, heritage may also be a factor in the sale of satellite-enabled services. Identifying heritage as a competitive advantage and defining its forms is important, because heritage in the context of corporate competitiveness has been largely ignored in economic geography and is not identified in the RBV literature (Billing, 2013). This is in spite of heritage seemingly being relevant to many other sectors, including automotive, aviation, rail and energy.

Heritage differentiates firms by signalling reliability to key stakeholders (including customers, investors, skilled individuals and collaborators), which encourages competence based trust (Galbreath, 2005; Mascitelli, 2000; Turban *et al.*, 1998). Competence-based trust is particularly important in BSRs governing the sale of satellites, where operators look to minimise risk by contracting a satellite manufacturer they trust. Therefore, heritage offers manufacturers a higher status in the market and leads to accumulative advantage (Billing, 2013; Podolny, 1993). Experienced operators and those that procure manufacturers with heritage are also advantaged in the satellite insurance and licensing process. Developing heritage takes time, since it necessitates involvement by a product or a firm in several satellite missions and for them to remain competitive for a lengthy period of time. Consequently, the value attached to heritage in the UK *space* sector encourages a monopoly of mature operators and manufacturers, who dominate the market (Agarwal *et al.*, 2002).

Once manufacturers have established their heritage, they have to sustain it through minimising risks by making only incremental changes to their products and processes. Therefore, heritage impacts on innovating routines, causing technological lock-in. This finding aligns with the evolutionary perspective on how previous actions and decisions "affect the probability" of the future behaviour of firms (Martin and Sunley, 2006:401). However, breaks with heritage are possible, since technological lock-in can be overcome (Van der Vooren, 2012:101). For example, regulatory and facilitative forms of governance have helped firms to be more radical in their approach to innovation, whilst changing customer needs have also prompted the same approach.

Innovative Capability

Innovation is important because it enables firms to address the "key buying criteria" of their customers (Hall, 1993:607), and is thus a key source of competitiveness (Ireland and Webb, 2007). For example, innovation in the manufacturing *space* sub-sector can increase the "*processing power of the satellite*" (L.Operator1a; L.DTHApplications2). A firm's innovative capability is a product of its innovating routines, which include: (i) "co-ordinating technological resources external to the firm"; and (ii) "adapting organisational practices to the requirements of radically changing technological opportunities" (Pavitt, 2002:119). Satellite manufacturers, operators and application providers all have different innovating routines and therefore take varying approaches to innovation. These differences, which are outlined in Table 8.2, are a factor of sector specific features or varying market conditions.

Table 8.2: Approaches to Innovation in the UK *Space* Sector.

Agent	Approach to Innovation
UK Satellite Manufacturers	Overall, the incentives for disruptive innovation in the telecommunications sector are low (Adlen, 2011; Van der Vooren, 2012). Therefore, rather than "*creating something from scratch*" through radical innovation, manufacturers will "*tweak*" existing satellite designs in an incremental way (S.Operator2b). These 'tweaks' typically focus on maximising capacity and increasing the "*processing power of the satellite*" (L.Operator1a; L.DTHApplications2).
	The Earth observation sector involves smaller, cheaper satellites, which are less risk averse and incorporate more 'cutting edge' components. Innovation aims to further reduce the costs of these satellites by standardising the production process and satellite designs "*as much as possible*" (L.Prime2a).
UK Satellite Operators	UK satellite operators view technological changes to satellites by manufacturers as part of their innovation. Additionally, the operators "*respond to demand issues*" and "*the complexity of* [their] *customers' needs*" through changing the frequency bands and orbits in which their satellites operate (L.Operator1d). Part of their everyday practices (routines) is to plan for these developments by exchanging ideas with manufacturers about what is technologically possible, and apply for the rights to orbital slots and frequency spectrum.
UK Satellite Application Providers	Much of the innovation impacting UK satellite application providers is carried out by the other parts of the UK *space* sector. However, they only benefit from the changes made by manufacturers and operators if they "*keep up to date*" with technological developments and new datasets becoming available (Mi.DataApplications1a). The application providers also innovate by "*trying to do something different with the* [satellite] *data*" (M.DataApplications1c). They find that they can be more radical in their approach to innovation because the sector is relatively young, with few "*other businesses doing what* [they] *do*" (L.VSATApplications1).

Source: Author.

These innovative practices depend on the firms adopting dynamic capabilities and accessing distinctive assets (such as skills, knowledge and finance) (Vega-Jurado *et al*., 2008; Damanpour *et al*., 2009). These assets are accessed through networks.

Networks

Networks are valuable to UK satellite companies because they lead to "increasing return affects" (Isaksen, 2014:2), as they widen the resource base of firms (Ellis, 2010; Hervas-Oliver and Albors-Garrigos, 2009). For example, networking with universities and other companies supports innovation, since it broadens firms' access to knowledge and maximises their awareness of market opportunities (Pollard, 2003; Ellis, 2010; Hervas-Oliver and Albors-Garrigos, 2009). Partnerships with other firms also creates opportunities for gaining intelligence or information on competitors, which proves valuable when developing competitive strategies. Customers and suppliers also contribute knowledge, which helps a firm to innovate and sustain or improve its market position (Fitjar and Huber, 2015; Bessant *et al*., 2012). Additionally, networks facilitate access to capital.

There are two sets of routines involved with developing networks, namely: (i) networking as a process; and (ii) if a relationships forms, the management of that relationship and other networks of partners. The networks are formed in both strategic and random ways, since even where a firm strategically seeks-out networking opportunities, randomly formed networks may be a by-product. For example, twenty-three UK *space* companies are based in Harwell, where they can strategically establish relationships with other firms and organisations, whilst also being exposed to opportunities for random network formation. Similarly, the number and variety of delegates who attend *space* conferences means random, as well as, strategic exchanges take place. This cross-over between strategic and random networks is a new contribution to the literature (Henn and Bathelt, 2015; Anderson and Wahlgren, 2015). Firms may also have the opportunity to form networks when they are involved in multinational projects (such as those funded by ESA) or with assistance from the Satellite Applications Catapult Centre.

Capital

Capital is not identified in the RBV as an internal resource, yet accessing is necessary for unlocking access to other sources of competitiveness (such as innovation) (Barney, 1991; Peteraf, 1993). Consequently, accessing capital is critical to the growth and competitiveness of both start-up and existing UK satellite companies (Pollard, 2003; La Rocca *et al.,* 2011; Christensen and Hain, 2013). Sector specific features determine the financial needs of firms and their ability to access different forms of capital, thus there are variations between satellite manufacturers, operators and application providers (La Rocca *et al.,* 2011). For instance, firms in the satellite manufacturing sector generally have low-profit margins and are therefore reliant on government grants, as well as manufacturing products outside of the *space* sector. Satellite operators have significantly higher margins and are less dependent on government grants. However, they require external finance, since the capital investment required for launching a new service exceeds their internal profits. Accessing this finance is helped by the operators' proximity to the City of London and their conservative approach to innovation (Sokol, 2013; Wójcik, 2009; Amini *et al.,* 2010). In contrast, value-added services are not as capital intensive as other parts of the space industry but are part of an immature sector that relies on the financial support of venture capitalists and business angels. These forms of external finance are accessed through networks, highlighting the interdependency of firm-based routines and also questioning the significance of an uneven geography of equity finance.

8.5 Revised Conceptual Framework

The conceptual framework for this research was outlined in Chapter 2 (Figure 2.2) and is based on the relationship between competitiveness, organisation and governance. The framework blends firm-level concepts from the competitiveness (Barney, 1991; De

Rassenfosse, 2012; Martin and Sunley, 2006; Phelps and Fuller, 2016), organisation (Gereffi *et al*., 2005; Smith, 1776; Harvey, 2014; Neilson *et al*., 2014) and governance (Jessop, 2011; Coen and Thatcher, 2008; Nadvi, 2008; Kooiman, 2000) literature, to provide an integrated way of thinking about how products and services are produced. This section provides a variant of the conceptual framework (Figure 8), which includes additions which specifically relate to the research findings on the UK *space* sector. These additions are outlined in detail below and coloured in blue in Figure 8. They include: (i) identifying the external factors which impact on production projects in the UK *space* sector; (ii) outlining the various tasks and subordinate projects within satellite production projects; (iii) providing detail on the types of BSRs which link the production projects; and (iv) identifying the internal resources which differentiate firms from their competitors.

The approach to understanding organisation within the conceptual framework was to identify a series of production projects (the PPT approach) (Bryson, 2008), explore the links between them (netchain literature) (Coe *et al*., 2008; Lazzarini *et al*., 2001), and outline when and how they are influenced by the industry's contextual framework (the texture approach) (Fineman and Hosking, 1990; Cooper and Fox, 1990) (Chapter 2, Section 2.4.1). In the UK *space* sector, these production projects either relate to: (i) satellite manufacturing; (ii) satellite operations; or (iii) the provision of satellite applications. Depending on whether the third production project (in this case application provision) is business-to-business (B2B) or business-to-consumer (B2C), there may or may not be a fourth production project namely, reselling. The different applications in the *space* sector include: transponder capacity for a DTH television broadcasting (B2B); a data package of Earth observation imagery (B2B) and; a positioning signal for satellite navigation (B2C). This detail of a fourth production project is another addition to the conceptual framework in Figure 8.

The production projects are interdependent and linked by outputs and two-way feedback loops (Coe *et al*., 2008:275; Lazzarini *et al*., 2001). The outputs feed directly or indirectly (through a network of resellers) into other projects. Figure 8 shows that the outputs can connect any of the three production projects. For instance, the *space* manufacturing and application projects are linked because application providers (specifically DTH providers) rely on manufacturers to supply receiver equipment. The links between the projects are governed by BSRs and the nature and extent of these relationships vary depending on the procurement moment and type of satellite involved (as shown in Figure 8). Each production project is managed by a lead firm or 'prime' (in the case of manufacturing), which manages a set of tasks and is dependent on access to internal resources through routines. Path dependency and sunk costs determine whether the firm will vertically integrate all of the production tasks or subcontract out a number of them. If tasks are subcontracted out they become subordinate projects, which are governed by BSRs. The subordinate projects are managed by sub-contractors, which involve another set of tasks, and require their own resources and routines. The subcontractors also outsource particular tasks, which will again become subordinate projects. The distinction between production projects and subordinate projects is a new contribution to the PPT literature and is a helpful extension of the understanding of complex production systems, which extend vertically, as well as horizontally.

The approach taken within the framework to understand the competitiveness of UK satellite firms is to identify the internal resources which differentiate those firms from their competitors (Barney, 1991; Peteraf, 1993). These resources are developed, accessed or performed through evolutionary routines, which may evolve over time. This is a generic argument which has been applied to studies of other sectors (Bryson and Ronayne, 2014; Phelps and Fuller, 2016). However, the research has added to this argument by identifying internal resources that have been ignored by the RBV literature (i.e. orbital slot/frequency spectrum and heritage). Additionally, the research has highlighted that the internal resources which provide a source of competitiveness vary depending on the production project (manufacturing, operations or application provision). These differences are illustrated in Figure. The sources of competitiveness for UK satellite firms are also influenced by the firms' BSRs, which determine the level of power firms hold in the relationship and what competencies their buyers most value (such as heritage, availability or cost). Heritage can lock firms in and out of these BSRs.

Governance forms part of the conceptual framework, as it is an external factor which impacts on the organisation and competitiveness of UK satellite firms. Additionally, Figure 8 identifies *space* geography and ground geography as other external factors. These factors interact with multi-scalar governance forms, as regulations are built on the physical constraints of the geography of the industry.

Impacted by External Factors or the 'Contextual Framework'

Regulatory and Facilitative Forms of Governance
- ITU Regulations and Outer Space Treaty.
- ESA and European Commission projects.
- Ofcom (Independent Regulatory Authority).
- UK Space Agency (Issuer of national *space* licences).
- Private insurers.
- Government organisations which facilitate market growth

Ground Geography
- Location of Earth station and launch sites.

Space Geography
- Frequency spectrum and orbital slot positioning.

Satellite Manufacturing

Designing satellites, manufacturing the components, integrating the components (during final assembly) and selling the satellite. Also, designing and manufacturing ground stations/receiver equipment.

Prime Manufacturer
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources (heritage, innovativeness, networks and capital)
- Routines
- External tasks (linked by BSRs)

Subordinate Projects
(e.g. payload manufacturing)

Sub-contractors
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources
- Routines
- External tasks (linked by BSRs)

Subordinate Projects

Projects are linked by: captive-relational type BSRs. Factors impacting BSR include:
- Heritage
- Availability
- Price

Feedback loops

Satellite Operating

Obtaining relevant orbital slots and frequency spectrum; financing the construction and launch of a satellite; and selling communication bandwidth, navigation signals or Earth observation data.

Operator
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources (orbital slots/frequency spectrum, heritage, innovativeness, networks and capital)
- Routines
- External tasks (linked by BSRs)

Subordinate Projects
(e.g. ground station operations, satellite launch, other operators)

Sub-contractors
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources
- Routines
- External tasks (linked by BSRs)

Subordinate Projects

Projects are linked by captive-relational type BSRs (if selling bandwidth) or modular or market type BSRs (if selling EO data). Factors impacting the BSR include:
- Footprint
- Sunk costs
- Availability
- Price

Feedback loops

Satellite Applications Provision

Distribute television signals to small dishes and satellite receivers
OR
Adds value to raw observation data and transforms that data into a usable information service.

DTH OR value-added service providers
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources (innovativeness, networks and capital)
- Routines
- External tasks (linked by BSRs)

Subordinate Projects
(e.g. manufacturing of receiver equipment)

Sub-contractors
(Path dependency/ sunk costs)
- Internal tasks
- Internal resources
- Routines

END USER OR PROJECT 4

Figure 8: Understanding the Competitiveness, Organisation and Governance of the UK Space Sector. (Note: BSRs are 'Buyer-Supplier Relationships')

Source: Author.

8.6 Lessons for Industry and Policy Makers

Key lessons can be taken from the research findings on the UK *space* sector to guide industry and future policy makers. This section presents the lessons in an accessible format, which distinguishes between those which relate to the governance, organisation or competitiveness of the industry.

Governance

- The nation state plays a central role in enforcing regulations and facilitating market growth. This highlights the importance of UK government involvement to the competitive success of the UK satellite industry.
- There is a dominance of regulatory forms of governance over facilitative forms of governance. Consequently, the impact of governance on the industry is more restrictive than enabling. There may be value in readdressing this balance.
- An over-reliance on ESA projects and government grants will create an 'artificial funding mechanism' that is vulnerable to the impacts of policy change and potentially detrimental to the long-term competitiveness of the UK satellite industry.
- There is evidence of government grants replacing private R&D which has meant technological innovation has remained at a constant level. Instead, grants need to supplement private R&D and increase overall activity in the industry. To achieve this, it is important for a government to not necessarily "fund the best proposals they receive", but instead fund the best proposals from those who are unlikely "to receive adequate funding from other sources" (Wallsten, 2000:84).

Organisation

- Satellite manufacturers, operators and application providers all manage their own production projects and divisions of labour, yet are interdependent. This means each require their own customised policy responses, yet impacts (positive or negative) on one sector will also impact on the others.
- Captive-buyer type BSRs can result in high associated costs, since the suppliers are under less pressure to price change and drive down costs. Therefore, the captive type BSRs governing the sale of ESA satellites may impact negatively on the price and innovativeness of the projects.
- More can be gained (such as the sharing of knowledge) from relational, as opposed to, captive type BSRs. Consequently, facilitating the development of longer term relationships between industry actors would be a valuable policy action.
- Commercial telecommunications operators are arguably the most powerful agent in the UK *space* sector, with both manufacturers and service providers dependent on them. It is important to understand who the key players are in order to know where to direct or not direct funding support.

Competitiveness

- The governance and organisation of production within the UK *space* sector impacts on firm-level competitiveness. Therefore, any actions in response to the lessons outlined above would have implications on the competitiveness of the sector.
- The key sources of competitiveness within the UK *space* sector are: (i) orbital slots and frequency spectrum; (ii) heritage; (iii) innovative capability; (iv) networks; and (v) capital. They are interdependent and support one another. An exception to this

is the relationship between heritage and an innovative capability, since heritage poses a barrier to disruptive change.

- Sector-specific features (manufacturing, operating or applications provision) determine the resource needs of firms and their ability to access them. Therefore, any facilitative forms of governance with the purpose of assisting firms in accessing resources would also need to be sector-specific.
- Heritage impacts on innovating routines by causing technological lock-in. Therefore, regulatory and facilitative forms of governance which help UK satellite firms to break with heritage are important.

8.7 Agendas for Further Research

As the first social science study of the UK *space* sector, this thesis has presented a number of important findings which can be applied to help understand the competitiveness, organisation and governance of other knowledge-intensive and high-risk sectors. It has also highlighted the spatial complexity of the *space* sector, with agents interacting on a local, regional and international scale; the pervasive nature of satellite-enabled applications within our everyday lives; and the verticality of our economy, since it relies on *space* based assets. In order to strengthen these contributions to the literature, there are three agendas for further research.

First, this thesis has demonstrated the value in blending theories between and within economic and political geography. First, the conceptual framework blended firm-level theories from the competitiveness (Barney, 1991; De Rassenfosse, 2012; Martin and Sunley, 2006; Phelps and Fuller, 2016), organisation (Gereffi *et al.*, 2005; Smith, 1776; Harvey, 2014; Neilson *et al.*, 2014) and governance (Jessop, 2011; Coen and Thatcher, 2008; Nadvi, 2008; Kooiman, 2000) literature, to provide an integrated way of thinking about how products and services are produced. Second, the approach to developing an understanding of firm-level competitiveness was to apply theory from both the RBV (Barney, 1991; De Rassenfosse, 2012; Dubois, 2015) and evolutionary perspective (Martin and Sunley, 2006; Bryson and Ronayne, 2014; Phelps and Fuller, 2016). The inclusion of the evolutionary perspective addressed the criticisms of the RBV being too static and failing to account for change (Priem and Butler 2001). Third, the theoretical approach to analysing the distribution of activities was to combine the PPT approach (Bryson, 2008), the netchain literature (Coe *et al.*, 2008) and texture models (Fineman and Hosking, 1990), to ensure that links between production projects and the projects' contextual framework were considered. Finally, economic and political points of entry on governance research were blended to address research gaps in each and deliver a "meaningful understanding" of an "industry and its governance" (Lewis *et al.*, 2002:433). This evidence of theoretical blending challenges future studies to refrain from adopting a singular approach to their research, in order to develop a more complete understanding.

Second, further study is required to understand the "complexities of heritage as a competitive advantage" (Billing, 2013:62). This would involve identifying other industries in which heritage is a source of competitiveness, comparing the different types of heritage (technology-based, relationship-based etc.), and how heritage is developed or overcome in varying circumstances. Additionally, research into the economic history of *space* firms would be valuable, identifying exactly when and how those firms have acquired heritage.

Finally, the research participants identified changes they anticipate will dramatically impact the character of the UK *space* sector. Exploring the impact of these changes would require future research on the sector. These changes include:

(i) The planned introduction of mega-constellations of micro satellites (cubesats) – this idea is driven by entrepreneurs (such as Elon Musk and Greg Wyler) who are willing to invest their own money in innovating satellite production processes, so that they can mass produce thousands of satellites at a low cost. This goes completely against the status quo of bespoke satellites taking three years to build and prime manufacturers charging premium prices on the basis of their heritage. In reality, more expensive, heavy satellites will still be required alongside microsatellites (Chapter 4, Section 4.2.2). However, the 'constellation revolution' may stimulate change in the manufacturing of heavier satellites too: "*if it works then it absolutely will change the industry forever*" (GovPolicy2b).

(ii) Commercial launchers providing increasingly lower cost access to *space* - linked to the increasing production of lower cost satellites, there is a demand in the market for lower cost launch provision. This challenge has been met by the emergence of commercial launchers (such as *Space*X and Reaction Engines) who aim to provide access to *space* at a fraction of the cost of existing providers. Satellite operators remain cautious of these new market entrants:

> "*Virgin Galactic will not be launching a London bus sized satellite from underneath one of his gliders, it isn't going to happen. They wouldn't even lift it, let alone anything else*" (L.Operator1a).

However, if the commercial providers can develop heritage, then lower cost access to *space* could lead to big changes in the market.

(iii) The replacement of satellite televisions with fibre-optic internet downloads and streaming - Television broadcasters are faced with a significant proportion of their customers downloading or streaming TV shows via fibre optic broadband (through services such as Netflix). This may, in the near future, make the broadcasting of live TV redundant and bring to an end contracts between operators and the largest DTH providers:

> "*Of our eleven million homes that have [DTH] boxes, seven million of them today are also connected to a broadband network and that number is increasing all the time. When we reach the point of all eleven million being connected to a broadband network and if that broadband network has enough capacity to deliver all the TV channels down it then we might start looking at whether it's worth trying to stay in satellites*" (L.DTHApplications2).

(iv) The outcome of the EU referendum negotiations - on June 23rd 2016, voters in the UK decided to exit the European Union a vote commonly known as 'Brexit'. Upon the UK government invoking Article 50 of the treaty on European Union (the formal mechanism by which a Member state leaves the EU), the EU and the UK will have two years to negotiate a withdrawal agreement (Malhotra, 2016). The outcomes of these negotiations are likely to impact on the UK *space* sector. Having said this, ESA is a separate entity to the EU and thus, the UK's participation in ESA projects is unlikely to be affected (Amos, 2016). Indeed, Norway and Switzerland are not in the EU, but are members of ESA. However, there is a threat of the UK being locked out of future *space* projects funded by the European Commission (such as Galileo and Copernicus) (Hollinger, 2016). Furthermore, there are other questions surrounding what the impact of 'Brexit' will be on UK trade and FDI, which may have further implications on the UK *space* sector.

APPENDICES

Appendix 1: Pilot Interview Schedules

<u>Interview Structure for Representatives of Florida Firms</u>

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the competitiveness and evolving economic geographies of space manufacturers in the UK and US. The specific focus is on:

- Characterising the UK and US *space* industry.
- Investigating the innovation systems that operate and the processes and knowledge sourcing that lie behind this.
- Exploring the geographies of production for space manufacturers.
- Understanding the relationships between different actors in the industry and assessing their impact upon firm competitiveness.
- Understanding the key influences over the formulation and development of UK and US *space* policy.
- Assessing to what extent economic planning in the UK and US, impact upon the competitiveness of *space* manufacturers.

The interview is divided into three short sections and will last approximately 2 hours. If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final thesis; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The thesis will be submitted in September 2016, at which time I would be happy to send you a copy.

Part 1: Context, Characteristics and Regulations

1. Could you please start by describing your professional background?
2. Could you please now give me a brief history of the firm, in terms of, when it was founded, what products it offers and the key markets it targets? Where is the history? Always here? Why?
3. And in terms of the types of products you produce, are your units customised to particular specifications or is it more of a standardised issue?
4. Do you manufacture any products that are 'spin-offs' to the space industry?
5. What is the legal structure of the firm? Is it a stand-alone branch or a subsidiary?
6. Is this the only site or is the firm part of a larger conglomerate?
7. Why is the firm located in this particular area? Are there any particular benefit that

8. comes with it being located here?
9. What proportion of your turnover comes from the space industry? Has this figure always been fixed? Has it shifted into this sector? When and why? When did you first become involved in the industry?
10. How many members of staff does the firm employ?
11. Who are your key customers? What proportion of your turnover is dependent on 1 or a small number of these customers? What percentage of these sales are exports?
12. Who are your major direct/indirect competitors? Are they US based or from overseas?
13. What would you say were your firm's three key main strengths, with regards to maintaining its competitive advantage?
14. And what would you say were the firm's key three main weakness?
15. What have been the biggest challenges that your firm has faced over the past three years? How have you overcome this? Looking back, what would you have done differently?
16. Are your products subject to any government regulations at all? If so, please could you specify and explain what impact these have?
17. To what extent do you interact with firms producing 'downstream' applications? Is the 'upstream' sector and the 'downstream' sector separate in the US, as it is in the UK.

Part 2: The Nature of the Firms' Competitiveness

1. What lies behind the competitiveness of the business? (Price or non-price based)
2. How many product innovations have the firm introduced over the past three years? Are these predominantly new products or changes/improvements to existing products? Who drives these innovations? Is it the company, the customers? How important is competition in the industry?
3. How many process innovations the firm introduced over the past three years? *(Process innovation means the implementation of a new or significantly improved production or delivery method).*
4. Would you describe these innovations (both product and process) as largely radical (new to the industry/market) or incremental (new to the firm)?
5. What percentage of the firm's turnover is reinvested into research and development?
6. How frequent is it for the firm to innovate solely on the basis of their in-house knowledge capabilities?
7. What other knowledge sources does the firm rely on? What proportion of ideas for innovation do these external sources provide?
8. Does this balance of in-house and external ideas vary between different projects or alter depending on whether the innovation is radical or incremental?
9. To what extent does the firm use information from customers as a source of ideas for innovation? If limited- Why? What are the barriers? If extensive? Why? What are the enablers?
10. Does the firm collaborate with competitors at all? If yes, in what form does collaboration take place (shared labour/training, exchange of information/expertise)? How important are these external barriers? How frequently do you interact? In what form does this interaction take place (Face-to-face

meetings/ telephone/ email exchanges)? How did you establish this relationship? What were the barriers?

11. Do you source knowledge from University Institutions? How do you manage the exchange of knowledge?
12. Does the firm engage in knowledge exchanges with any research laboratories? If so, what has enabled you to do this? What are the barriers?
13. Which of the following do you rely on the most for insight and knowledge: Customers, competitors, universities, independent entrepreneurs, investors, scientists, or suppliers
14. Who is in charge of screening and selecting innovation ideas for funding and development?
15. To what extent does the firm rely on external market research/ advertising agencies for bringing new innovations to market? What are the enablers/ barriers?

Part 3: Geographies of Production

16. Are there any other space companies nearby? Is this something you were aware of when you decided to locate here?
17. Where is your nearest University Institution? Do you interact with them? In what capacity? Would you opt to collaborate with them over other University Institutions?
18. Where do your customers come from? What proportion of them are from the US, UK, Rest of Europe, Asia Pacific?
19. Where does your knowledge come from? What locations are important in terms of learning? What proportion of your external knowledge sourcing is UK/US based?
20. How do you manage the exchange of knowledge over a long distance?
21. What is your opinion of long distance exchanges of knowledge?
22. Are any of your suppliers based outside of the UK/US? What advantages does their location offer you?
23. Do any parts of your production process demand geographic proximity? If so, what and why?
24. How important would you say spatial planning is to the space industry? Does this occur at a national, regional or local level at all?
25. Would you describe the space industry as a global industry?
26. How important is networking to the competitiveness of firms?
27. How would you describe your relationship with small firms/prime contractors?
28. Would you describe your value-chain as global or localised?

Part 2: Policy, Environment and Funding (trying to ascertain the scale of policy and engagement).

1. How important is the Government to the space industry?
2. How would you characterise the present US Government's attitude to the *space* industry? Has this attitude changed in recent years?
3. What would you say were the key influences over the formulation and development of the present US *space* policy?
4. Which of the following do you feel presents the biggest barrier to success of the US

space industry? a) lack of knowledge, b) lack of financial capital, c) shortage of skills. Please give reasons why. Do you feel that economic planning is addressing this barrier? What more could be done? What should the future direction be for the government's policy framework?

5. Is the firm in receipt of any government funding? Is it direct (straight from the government) or indirect (via other layers in the value chain)? If so, how important is it to the competitiveness of the firm? What more could be done? What should the future direction be for the government's policy framework?
6. Were you given any incentives to specialise in this area at all?
7. What would you say the key benefits were for a *space* manufacturer being located in Florida?
8. Are there any NGO/Government organisations operating in Florida that are critical to your competitiveness? Are these local organisations or to they extend their reach to a national scale?
9. Do you interact with any government funded bodies or organisations? If so, how would you describe your relationship?
10. In your opinion, do the skills of US graduates meet the demands of high-tech industries such as yours? If no, elaborate on the skills deficit you have experienced? Are you aware of any hard-to-fill vacancies? What action needs to be taken?
11. Is there any supportive infrastructure (soft or hard) available to you at a local level? If so please elaborate on its function and how effective you find it.
12. Do you find there are issues of copying in the industry at all? How is this managed?

Interview Structure for Florida participants in Agencies/Organisations

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the competitiveness and evolving economic geographies of space manufacturers in the UK and US. The specific focus is on:

- Characterising the UK and US *space* industry.
- Investigating the innovation systems that operate and the processes and knowledge sourcing that lie behind this.
- Exploring the geographies of production for space manufacturers.
- Understanding the relationships between different actors in the industry and assessing their impact upon firm competitiveness.
- Understanding the key influences over the formulation and development of UK and US *space* policy.
- Assessing to what extent economic planning in the UK and US, impact upon the competitiveness of *space* manufacturers.

The interview is divided into three short sections and will last approximately 1 hour. If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final thesis; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The thesis will be submitted in September 2016, at which time I would be happy to send you a copy.

Part 1: Policy, Environment and Funding (trying to ascertain the scale of policy and engagement).

1. Could you please start by describing your professional background? Is there any issue with people moving between firms/organisations?
2. Could you please explain the role of this organisation?
3. How many members of staff does the organisation employ?
4. How important is the Government to the space industry?
5. How would you characterise the present US Government's attitude to the *space* industry? Has this attitude changed in recent years?
6. What would you say were the key influences over the formulation and development of the present US *space* policy?
7. Which of the following do you feel presents the biggest barrier to success of the US *space* industry? a) lack of knowledge, b) lack of financial capital, c) shortage of skills. Please give reasons why. Do you feel that economic planning is addressing this barrier? What more could be done? What should the future direction be for the government's policy framework?
8. Are you in receipt of government funding? Is it direct (straight from the government) or indirect? How dependent are you on that funding? What more

could be done? What should the future direction be for the government's policy framework?

9. What would you say the key benefits were for a *space* manufacturer being located in Florida?
10. What firms do you interact with? Are these local firms or do you extend your reach to a national scale? How would you describe your relationship?
11. In your opinion, do the skills of US graduates meet the demands of high-tech industries such as yours? If no, elaborate on the skills deficit you have experienced? Are you aware of any hard-to-fill vacancies? What action needs to be taken?
12. What supportive infrastructure (soft or hard) is available Florida space firms at a local level? If so please elaborate on its function and how effective you find it.
13. Do you find there are issues of copying in the industry at all? How is this managed?

Part 2: Context, Characteristics and Regulations

Please reflect on the characteristics of the space manufacturers you know of in Florida.

18. What lies behind the competitiveness of the businesses? (Price or non-price based)
19. Are their products usually customised units to particular specifications or more of a standardised issue?
20. Are you aware of any 'spin-off' products coming out of the space industry?
21. Are the majority of Florida's space manufacturing firm SME's (fewer than 250 people) or large?
22. What is the most common legal structure of the firms? Are they stand-alone branches or a subsidiary?
23. What makes the firms choose to locate in Florida? Are there any particular benefits to being located here?
24. What percentage of the firms sales are exports?
25. Who are their major direct/indirect competitors? Are they US based or from overseas?
26. What would you say were the three key main strengths of the Florida Space Industry, with regards to maintaining its competitive advantage?
27. And what would you say were the key three main weaknesses?
28. Are the space products manufactured in Florida subject to any government regulations at all? If so, please could you specify and explain what impact these have?
29. Is the 'upstream' sector and the 'downstream' sector separate in the US, as it is in the UK.
30. Where does the knowledge come from? What locations are important in terms of learning? What proportion of the external knowledge sourcing is US based?
31. How do they manage the exchange of knowledge over a long distance?
32. What is your opinion of long distance exchanges of knowledge?
33. Are you aware of any suppliers based outside of the US? What advantages does their location offer you?

<u>Part 3: The Nature of the Firms' Competitiveness</u>

Geographies of Production: The Geography of customers and supply chain-

29. Would you describe the US space industry as a local, national or global industry? Please explain why.
30. Identify and rank order the Universities that the local space firms interact with- for research and other purposes. Are they sources of talent?
31. Where is your nearest University Institution? Do you interact with them? In what capacity? Would you opt to collaborate with them over other University Institutions?
32. How important would you say spatial planning is to the space industry? Does this occur at a national, regional or local level at all?
33. Would you describe the space industry as a global industry?

Appendix 2: Participant Information Sheet (cover letter)

PhD Title: Competitiveness and the Evolving Economic Geographies of the UK *Space* Sector

Description of the study

This research interest comes from the industries growing contribution to the Global economy and the potential for space applications to benefit individuals and businesses anywhere on the planet. The specific focus will be on:

1. To identify and understand the changing economic geography of the satellite industry.
2. To understand the competitiveness, organisation and governance of the UK space sector.

Research Objectives:

- To characterise the UK *space* industry. Include a description of the firms involved, their geography and the market conditions.
- To explore the geographies of production for *space* manufacturers, with reference to the economic organisation of their value chains.
- To understand the key sources of competitiveness for UK satellite firms and to introduce orbital slots and frequency spectrum as competitive assets.
- To investigate the impact of different forms and scales of public and private governance on different stages of production.
- To understand the relationships between different actors in the industry and assess their impact upon the competitiveness of the UK *space* sector.

Invitation to participate and explanation of what participation entails

You are invited to participate in the study because you hold a significant position within a company of interest for the research. Participation is voluntary and if you choose to participate, you are free to withdraw at any time without reason.

By participating you will agree to be interviewed in regard to the company you are employed by and your role within the firm. The interview will last approximately 1 hours. The content of the interviews will not be shared with other participants either from within your firm or other participating firms.

The verbal interview will be recorded unless you state that it would be preferential not to. This is to ensure the accuracy of data and mitigate misrepresentation.

A summary sheet of the interview will be provided for you to check the accuracy of the researcher's interpretation of the interview. Where inconsistencies arise, the researcher will reassess the interview in light of the participant's comments. However, full editorial control of the research outputs remains with the researcher.

The space industry is an important area that requires academic research to further our understanding of the sectors contribution to the economy. With this in mind I really hope you will consider participating in this project. If you require further clarification, please contact the researcher prior to participating.

Confidentiality/anonymity and data security

The data generated will be treated as confidential. Both the participants and their organisations will remain anonymous in the outputs of the research, unless a participant specifically asks for a comment to be made identifiable.

I can assure you that if you were to participate, then any information would be safely stored in accordance with the Data Protection Act (1998). Access to the data will be restricted to the researcher. Both electronic and hard copies will be stored securely, through password protection and a locked filing system. On completion of the study, the data may be deposited in the Economic and Social Research Council (ESRC) data archive. If this occurs, all identifiable information for both participant and company will be removed.

Results of the study

Participants will be sent a copy of the executive summary of the study once completed.

The results of the study will be used to form an unpublished PhD thesis. Results may also inform published work done by the researcher.

Funding of Study

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council, a UK Government funded body, under the supervision of Professor John Bryson and Dr Lauren Andres.

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Appendix 3: Consent Form

Thank you for agreeing to take part in this interview. Please read and sign below to acknowledge you have read and understood the information provided, and give your consent for the interview process to continue.

Please read and indicate:

The researcher has provided me with 'participant information sheet' and I understand the project.	Yes / No
I have had the opportunity to ask questions or for more information.	Yes / No
I understand that taking part in the research is voluntary and that I am free to withdraw from the project at any time, without giving any reason.	Yes / No
I understand that I can take a break at any time and that I can chose not to answer a question.	Yes / No
I understand that any information I give will be confidential. Quotes from interviews may be used when the researcher writes about the project, but I will not be identified in any way in the research findings or other publications or outputs from the research.	Yes / No
I agree to take part in the research and to be interviewed by a researcher.	Yes / No
I am happy for the interview to be audio-recorded.	Yes / No

Participant Name ……………………………………………

Participant Signature ……………………………………………

Date ……………………………………………

Appendix 4: Interview Codes (to anonymise the firm names)

Case Category	Code (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)
Prime Satellite Manufacturers	L.Prime1
	L.Prime2
	M.Prime1
	M.Prime2
Launcher Manufacturer	S.LauncherManufacturer1
Ground Systems Manufacturer	S.GroundSystems1
	S.GroundSystems2
Communications Operator (UK company)	L.Operator1
	L.VSATApplications1
	M.Operator1
	M.Operator2
	S.VSATOperator1
	S.Operator1
	Mi.Operator1
Communications Operator (UK sales office)	S.Operator1
	S.Operator2
	S.Operator3
	S.Operator4
DTH Broadcaster	L.DTHApplications1
	L.DTHApplications2
Earth Observation Applications Provider	L.DataApplications1
	L.DataApplications2
	S.DataApplications1
	S.DataApplications2
	S.DataApplications3
	Mi.DataApplications1
	Mi.DataApplications2
	Mi.DataApplications3
Geographical Information Services	M.DataApplications1
	S.DataApplications1
Satellite Insurance Provider	L.Insurer1
	L.Insurer1
Space Legal Practioner	L.Law1
Government Minister	GovMinster1
Government Policy Organisation	GovPolicy1
	GovPolicy2
	GovPolicy2
Government Facilitator of Policies	GovFacilitator1
	GovFacilitator2

Government Regulator	GovRegulator1
Government Defence Organisation	GovDefence1
Government Research Centre	S.GovResearch1
	S.GovResearch2
	L.GovResearch1

Dates of Interviews and Codes

UK Based *Space* Manufacturers

Note: The UK based companies may be a subsidiary of a larger parent company, but the number of employees accounts for those based in the UK.

	Date of Interview	**Code (Interview)** (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)
1	19/03/2015	L.Prime1a
2	15/04/2015	L.Prime1b
3	13/01/2015	L.Prime1c
4	06/03/2015	L.Prime1d
5	16/03/2015	L.Prime2a
6	26/11/2014	L.Prime2b
7	31/20/2014	L.Prime2c
8	23/10/2014	M.Prime1a
9	14/07/2015	M.Prime2a
10	04/03/2015	S.SystemsManufacturer1a
11	01/12/2014	S.SystemsManufacturer1b
12	01/05/2015	S.LauncherManufacturer1a
13	11/11/2014	S.LauncherManufacturer1b

Satellite Operations

	Date of Interview	**Code (Interview)** (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)
14	26/03/2015	L.Operator1a
15	14/11/2014	L.Operator1b
16	02/12/2014	L.Operator1c
17	10/12/2014	L.Operator1d
18	02/02/2015	M.Operator1a
19	02/02/2015	M.Operator1b

20	07/11/2014	M.Operator2
21	31/03/2015	S.Operator1a
22	18/03/2015	S.Operator1b
23	09/03/2015	S.Operator2a
24	12/11/2015	S.Operator2b
25	05/05/2015	S.Operator2c
26	12/11/2015	S.Operator3a
27	20/11/2015	S.Operator3b
28	04/12/2014	S.Operator3c
29	17/11/2014	S.GroundSystems1
30	28/10/2014	S.GroundSystems2

Satellite Applications Provider

	Date of Interview	**Code (Interview)** (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)
31	11/11/2015	L.DataApplications1
32	10/03/2015	M.DataApplications1a
33	02/02/2015	M.Applications1b
34	03/12/2015	M.DataApplications1c
35	03/12/2015	M.DataApplications1d
36	26/11/2014	S.DataApplications1
37	22/10/2014	Mi.DataApplications1a
38	19/11/2015	Mi.DataApplications2
39	04/11/2015	Mi.DataApplications3
40	24/11/2015	L.VSATApplications1
41	04/11/2015	S.VSATApplications1
42	14/11/2015	L.DTHApplications1
43	31/03/2015	L.DTHApplications2
44	27/02/2015	Mi.DTHApplications1

Government Institution

	Date of Interview	**Code (Interview)** (L.) Large Firm (>250) (M.) Medium Sized Firm (50-250) (S.) Small Firm (10-49) (Mi.) Micro Firm (<9)
45	06/01/2015	GovPolicy1
46	27/02/2015	GovPolicy2a
47	04/03/2015	GovPolicy2b
48	01/12/2015	GovPolicy2c
49	03/03/2015	GovDefence1a
50	14/04/2015	GovDefence1b
51	04/12/2015	GovApplications1
52	15/01/2015	GovPolicy3a

53	10/04/2015	GovPolicy3b
54	15/04/2015	GovPolicy3c
55	25/11/2014	GovPolicy3d
56	25/11/2014	GovPolicy3e
57	14/07/2015	GovPolicy3f
58	10/04/2015	GovFacilitator1a
59	02/04/2015	GovFacilitator1b
60	25/11/2014	GovFacilitator1c
61	14/11/2015	GovRegulator1
62	11/11/2014	GovFacilitator2a
63	11/11/2014	GovFacilitator2b
64	23/02/2015	GovFacilitator2c
65	30/03/2015	GovFacilitator2d
66	10/04/2015	GovFacilitator2e
67	05/03/2015	GovPolicy4
68	11/04/2015	S.GovResearch1
69	04/12/2015	S.GovResearch2
70	30/03/2015	L.GovResearch1

Satellite Insurance Provider

	Date of Interview	**Code**
71	12/03/2015	L.Insurer1
72	12/03/2015	L.Insurer2

***Space* Legal Practioner**

	Date of Interview	**Code**
73	05/05/2015	L.Law1

US (Florida) Interviews

	Date of Interview	**Code**
74	31/03/2014	FloridaLaunchSiteContractor1
75	01/04/2014	FloridaSubsystemsManufacturer1
76	01/04/2014	FloridaLaunchManufacturer
77	02/04/2014	FloridaGovFacilitator1a
78	02/04/2014	FloridaGovFacilitator1b
79	31/03/2014	FloridaGovFaciltator1c
80	01/04/2014	FloridaGovFacilitator2
81	02/04/2014	FloridaGovFacilitator3
82	03/04/2014	FloridaGovFacilitator4
	05/04/2014	FloridaGovFacilitator5
83	05/04/2014	FloridaConsultant1a
84	04/04/2014	FloridaConsultant1b

Appendix 5: Interview Schedules

<u>Interview Schedule for Prime Manufacturer</u>

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the organisation and governance of the production of UK space systems.

If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final dissertation; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The dissertation will be submitted in September 2016, at which time I would be happy to send you a copy.

Part 1: Background/Product Questions

1. What does this branch/facility/company do? (*prompts: pure manufacturing; servitized manufacturing; pure services*)
2. (*If not covered in question 1*) Could you please give me a brief history of the firm, in terms of, when it was founded, the key markets it targets, whether it is the only site or part of a larger conglomerate?
3. (*If not covered in question 1)* What proportion of your business comes from the space industry? Has this figure always been fixed (*separate from aircraft*)? Has it shifted into this sector? When and why? When did you first become involved in the industry?
4. Can you tell me something about your customers? What proportion of your turnover is dependent on one or a small number of these customers? Which satellite product is currently in the highest demand?
5. What percentage of these sales are exports? To which countries are they exported? (*Prompt- the company may not export the service themselves, but their offering may be part of somebody else's exported product*)
6. Who are your major direct/indirect competitors? Are they British based or from overseas?
7. Why is the firm located in this particular area? Are there any particular benefits to the firm by being located in the UK? Why not elsewhere in Europe? (*Prompts: the importance of FDI*) What are the benefits to being located in this region?
8. Could you please outline your key products? Do you offer operational services, as well as, the manufacture of satellites? Do you operate that service yourself or do you outsource the responsibility?
9. *(If manufacture satellites)* How many satellites do you produce a year?
10. *(If operate satellites)* How many do you currently operate in orbit? Which orbit/frequency? Why? Of the satellites you are operating, what proportion of your capacity do you use? Why?

11. Do you lease orbital spectrum to service providers? Are you leasing orbital spectrum from other operators? What is the nature of that relationship?
12. In the past have you exchanged one orbital slot for another? What were the terms of this exchange?

If servitized manufacturing…

13. Has the company always offered operational services? If not, when did the company servitize? (*Prompts: to lock out competitors; to lock in customers; to increase the level of differentiation; advantages over hardware products; a growth in opportunities in the satellite service sector*).
14. What satellites services does the company consume from external providers?
15. What proportion of your revenue is made up of services?
16. What margin of profit do you make on the services? How does this compare to the sale of the satellite (*prompts- is it twice/three times that of a satellite*)?
17. To what extent do you agree with the statement 'the primary product of a satellite mission is the 'content that is transmitted' or data'? Please explain.
18. Do you have multiple transponder agreements on your satellites? How many? How do you manage this? Do you have transponder agreements with other satellite operators?
19. Is your relationship with your manufacturing customers different from your service customers? Please give examples.
20. To what extent has your move towards a service-oriented strategy meant you have had to adapt your organisational structures and processes? Did the addition of services demand additional assets for example?
21. Is your relationship with the buyers of your manufactured product different from the buyers of your service offering? Please give examples

Part 2: Organisation and Governance of Production

22. What are the principle design drivers of your satellites? (Prompts: customer requirements, technical demands, regulations)? Please give examples.
23. Are there satellites that are more generic/standardised and those that are more customised?
24. Is the manufacturing of satellites a short term business i.e. if you are building the best, most reliable satellite does not mean that your market is getting smaller?
25. To what extent is your production process fragmented (parts are physically separated across disparate locations)? How many different companies are involved? What impact does this fragmentation have?
26. Can we explore the different stages involved in satellite production? Which of these stages do you perform in-house? What factors influence your decision to perform these stages in-house?
27. (*If outsource subsystem and software manufacturing*) If the subsystems and software are the 'brain' of a satellite- how important is it that you facilitate an exchange of information between the supplier and service provider? What processes are involved in this? (*Prompts: systems engineering*)
28. Tell me where the various parts come from within satellites? Are they all provided in-house by your form? *If not*- Are they outsourced /locally/globally/to one of your subsidiaries?

29. To what extent is your production network global? Which stages are outsourced? What are the implications of this? How do you coordinate this? To what extent do network actors behave differently in different national contexts?
30. Do you upgrade your satellites after a period of time? *If yes*- How do you do this? After how long? *If no*- why not? (*Prompt: expense?)*
31. Are your responsible for decommissioning the satellite at the end of its use? *If yes*- At what cost? How do you do this? Does this factor into your initial design?
32. Are you responsible for the ground control systems of the satellite? Do you operate that in-house or do you outsource to an external-provider? Where are they located? What costs does this incur?
33. Do you have any subsidiaries? *If yes*- When/how were they formed? What products do they offer? Why not offer their product as your own? What is the nature of your relationship? *(Prompt- do you exchange information? Are you there preferential supplier? Do they provide you with access to a satellite service?)*
34. Tell me about the organisation of production of a recent satellite project you have been involved in. (*Prompts: What was involved? Who was involved? Who set the product specifications/schedules and controlled the strategic functions? Who held the intellectual and industrial property for the product? What were the implications of this?)*
35. I would now like to ask you some questions about the extent and nature of your relationships with your customer:
    a. Give me an example of when you have openly shared information with a customer. For example, involving them in the early stages of product design; sharing cost information; discussing future product development plans). Does this happen in all cases?
    b. For how many clients do you link your systems/procedures/routines to theirs? *(Prompt- at one extreme the two organisations will operate independently, at the other extreme their systems will be 'intercoupled' to help facilitate operations).* Please give examples.
    c. What's distinctive about the contractual agreements relating to satellites?
36. Could you tell me about the last three transactions you had with your customers? (*Prompts: how complex were the transactions; did they require frequent face-to-face interactions; could information be exchanged be codified*).
37. How do you insure your products and services?

Part 3: Impact of Regulation

38. What are the most important regulations that affect your business? Please list and explain.
39. What does the firm do to ensure compliance with these regulations? (*Prompt- Do you rely on in-house/external legal advisors?*)
40. Has the firm had any involvement in shaping regulation? Role of trade association?
41. How do UK space regulations differ from global and other national standards? What does this mean for your business?
42. Please would you describe the process of securing UK orbital slots? Whose responsibility is it? How straightforward is the process? How important is the role of OFCOM?

43. Article 44 of the ITU constitutions states that: ‘members shall endeavour to limit the number of frequencies and the spectrum used to a minimum’. How do you ensure this? How important is this constitution?
44. Please would you explain a coordination process you recently underwent?
45. Are you in a situation where you are a secondary service in an allocated slot and may operate, but are unable to cause any interference to the other service? How do you manage this?
46. Do you currently have any paper satellites? Please give examples.
47. What challenges and opportunities are currently facing firms that are using satellites for the delivery of services? (Prompts: *bandwidth constraints, technological solutions*).

Interview Schedule for Satellite Operator

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the organisation and governance of the production of UK space systems.

If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final dissertation; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The dissertation will be submitted in September 2016, at which time I would be happy to send you a copy.

Part 1: Background/Product Questions

1. What does this branch/facility/company?
2. (*If not covered in question 1*) Could you please give me a brief history of the firm, in terms of, when it was founded, the key markets it targets, whether it is the only site or part of a larger conglomerate?
3. (*If not covered in question 1*) Could you please outline your key products and services? What factors most influenced this product/service choice? (*Prompts- customer requirements, technical requirements, international regulation, accreditation*).
4. (*If not covered in question 1)* What proportion of your business comes from the space industry? Has this figure always been fixed (*separate from aircraft*)? Has it shifted into this sector? When and why? When did you first become involved in the industry?
5. Can you tell me something about your customers? *(Prompts: What proportion of your turnover is dependent on one or a small number of these customers? Which satellite product is currently in the highest demand?)*
6. What percentage of these sales are exports? To which countries do you export to? (*Prompt- the company may not export the service themselves, but their offering may be part of somebody else's exported product*)
7. Who are your major direct/indirect competitors? Are they British based or from overseas (*location of facility or ownership*)?
8. What are the advantages/disadvantages of the firm being located here? Are there benefits to the firm being located in the UK? Why not elsewhere in Europe? (*Prompts: the importance of FDI*)? What are the benefits to being located in this region?
9. Do you operate your own satellites or lease bandwidth from other providers? Why? What are the implications of this? (*Prompt: Are you dependent on an external bandwidth supplier? What constraint does this place on your business?).*
10. (*If a satellite operator*) Do you have multiple transponder agreements on your satellites? How many? How do you manage this? Do you have transponder agreements with other satellite operators?

Part 2: Nature extent of relationships with upstream suppliers

11. What is your involvement in the ground control systems of your satellites? Do you do this in-house or outsource to an external provider? Where are they located? What costs does this incur?
12. (*If not covered in question 1*) Are you a subsidiary of a larger firm? What is the nature of your relationship with your parent company? *(Prompts: Do you exchange information? Are they your preferential supplier?).*
13. Tell me about the organisation of production of a recent project involving satellites you have been involved in. (*Prompts: What was involved? Who was involved? Who set the product specifications/schedules and controlled the strategic functions? Who held the intellectual and industrial property for the product? What were the implications of this?)*
48. I would now like to ask you some questions about the extent and nature of your relationships with your customer:
    a. Give me an example of when you have openly shared information with a customer. For example, involving them in the early stages of product design; sharing cost information; discussing future product development plans). Does this happen in all cases?
    b. For how many clients do you link your systems/procedures/routines to theirs? *(Prompt- at one extreme the two organisations will operate independently, at the other extreme their systems will be 'intercoupled' to help facilitate operations).* Please give examples.
    c. What's distinctive about the contractual agreements relating to satellites?
14. Could you tell me about the last three transactions you had with your satellite suppliers (transponder agreements)? (*Prompts: how complex were the transactions; did they require frequent face-to-face interactions; could information be exchanged be codified*).
15. Can you tell me about insuring your products and services?

Part 3: Impact of Regulation

16. What are the most important regulations that affect your business? Please list and explain.
17. What does the firm do to ensure compliance with these regulations? (Prompt- Do you rely on in-house/external legal advisors?)
18. Has the firm had any involvement in shaping regulation? Role of trade association?
19. How do UK space regulations differ from global and other national standards? What does this mean for your business?
20. What challenges and opportunities are currently facing firms that are using satellites for the delivery of services? (Prompts: *bandwidth constraints, technological solutions*).

<u>Interview Schedule for Regulatory Actor (e.g. representative of UK Space Agency, OFCOM)</u>

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the organisation and governance of the production of UK space systems.

If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final dissertation; however, your details and the firm’s name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The dissertation will be submitted in September 2016, at which time I would be happy to send you a copy.

Global Governance

1. What role does the UK play in forming International space regulations?
2. Could you please start by explaining your role in UK space regulations?
3. Please could you explain what you consider the role of the ITU to be?
4. What principles form/modify ITU space regulations? Which of these principles are more or less important?
5. How long have these regulations been established for? Have they recently been revised to reflect the significant changes to the UK space market? If not, then why? What implications has this had?
6. Are there currently any issues with ITU regulations? Is there need for any changes/alterations to be made?
7. Please could you explain the ITU procedure of securing am orbital slot?
8. What does being a member of the ITU ensure for the UK space industry? Please give any examples of where UK membership has been significant?
9. What role does the Space Service department play? How does their work compare to the ITU?
10. “ITU has no enforcement powers of its own. As long as procedures are followed it does not have the authority to approve or reject application for satellites that may be dubious”. What are the implications of this?
11. According to the IGS 2013 “The key element in supporting the continued growth of the UK space sector is to ensure access to radio spectrum and orbital slots”. How straightforward is this target? What steps can be taken by the Government to ensure it is achieved?

National Governance

1. Could you please explain your role in the UK satellite industry?
2. Do you play a role in forming International space regulations?

3. Have there been any key changes in recent years to UK to UK space regulations? Please give examples.
4. How unique are UK space regulations? How do they compare to other bodies in different national contexts?
5. What principles form/modify UK and International space regulations? Which of these principles are more or less important?
6. How long have the current UK space regulations been established for? Have they recently been revised to reflect the significant changes to the UK space market? If not, then why? What implications has this had?
7. Are there currently any issues with UK and international space regulations? Is there need for any changes/alterations to be made?
8. Typically what size firm do you work with? Are they satellite operators or manufacturers or service providers? What's the balance?
9. Who holds the most orbital slots in the UK? What factors have led to them holding the most slots? What are the implications of this?
10. How have some companies become dominant/ major players in controlling slots?
11. Are you aware of any cases where UK orbital slots have been exchanged? If so, what were the conditions for the exchange?
12. Are orbital slots a free hold or a lease hold agreement? (If you own the freehold, it means that you own the building and the land it stands on outright, in perpetuity. It is your name in the land registry as "freeholder", owning the "title absolute"… Leasehold means that you just have a lease from the freeholder (sometimes called the landlord) to use the home for a number of years).
13. What are the legal precedents linked to space law?
14. According to the IGS 2013 "The key element in supporting the continued growth of the UK space sector is to ensure access to radio spectrum and orbital slots". How straightforward is this target? What steps can be taken by the Government to ensure it is achieved?
15. We've talked about ITU and the space service department and primary regulations, are there any other UK regulations that constrain or enable the British space market?
16. According to the Outer Space Treaty: "Outer space is not subject to appropriation by any one country; all nations have equal rights and access to the resources of space". What does that mean in practice? Is it not contradictory when actually first come first served.
17. Radio spectrum and satellite orbits are referred to as a 'limited natural resource'- what are the implications of this for the future of the UK satellite industry?
18. Do space regulations reduce innovation in the space industry/have they held back innovation?
19. How integrated is the UK upstream and downstream sector? How much interaction is had between `them? Can you offer any examples?

Interview Schedule for Representative of ESA

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the organisation, governance and competitiveness of the of the UK satellite industry. If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final dissertation; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The dissertation will be submitted in September 2016, at which time I would be happy to send you a copy.

A key part of my thesis is understanding the Governance of the UK satellite industry, so this interview is really aimed at accessing the role of ESA and how that looks alongside other political influences.

Structure of ESA

1. Start by explaining the role of the European Space Agency? Is it a regulator or a facilitator or both?
2. How much autonomy does the European Space Agency have? Who does ESA answer too? Who sets the initiatives? Who sets the constraints?
3. How is it different from National Space Agency's?
4. Could you please describe the structure of the European Space Agency?
5. Would you please give me an example of a project that you are currently working on that demonstrates the typical role that ESA plays?
6. Describe the process by which ESA programmes are brought into place?

ESA and National Space Agency's

7. How much influence does ESA have over European Nation State's actions? Please give examples.
8. Set any regulations/barriers which European member states have to comply with? Ground rules?
9. To turn it round…. How much influence do European Nations State's have over ESA's actions?
10. Is the UK's influence greater or less than other European countries?
11. Have there been any changes in recent years to this ESA/UK relationship? Any shifts in power?
12. How significant is it that the ECSAT centre is here in the UK?
13. How much influence do the Large Primes have over ESA programmes? What does that relationship look like? Has this changed at all and why?
14. Is there evidence of state power moving upwards/outwards?

ESA and the ITU

15. What is the relationship between ESA and the ITU? What does the ITU hold ESA accountable for? How frequent are these exchanges?
16. Does ESA have any power to influence the actions of the ITU? Give example?
17. Is ESA responsible for negotiating Spectrum with the ITU on behalf of its member states?
18. Are there any challenges currently facing the ITU?
19. Are there any other supranational institutions involved in the space industry?

Hierarchy of Power

20. Out of the ITU, ESA and National Space Agency's which has the most power over UK satellite companies? Integrated Applications?
21. Is there a hierarchy of power at all between these three? Where one is more important than the others? Define what that power looks like- in what way is it is more important?
22. A central power or a network of nodes?
23. Describe the circulation of power between the ITU, ESA and National Space Agency's? Is it vertical rather than horizontal?

General Questions

24. How different are European space industries from one another. For example, how does the UK and French Space Industry compare? How are they similar/different
25. We have spoken about ESA, the ITU, National Space Agencies and Large Primes. Are there any other organisations that govern the UK satellite industry.
26. What are the biggest challenges and opportunities currently facing ESA?
27. Is it difficult to meet the expectations of all member states? How is this dealt with?
28. The industry can be very conservative with a large emphasis on heritage- what does ESA do about this?

Interview Structure for Government Facilitator

Introductory Brief

This research is being undertaken as part of a PhD funded by the Economic and Social Research Council that is investigating the organisation and governance of the production of UK space systems.

If you would like me to clarify any of my questions then please just ask or if there are any that you wish not to answer, then that it is absolutely fine and we can just move on. With your consent, the interview will be tape recorded and later transcribed by myself. Any information given may feature in the final dissertation; however, your details and the firm's name will be anonymous. Any other data will be stored safely and in accordance with the Data Protection Act 1998. The dissertation will be submitted in September 2016, at which time I would be happy to send you a copy.

1. Could you start by explaining the role of the Catapult Centre? It's History? Why it came about?
2. In order to receive your support, do the companies need to be UK based or UK owned?
3. Describe a typical company you would support- SME's?
4. Do your provide services yourself? Do you operate your own satellite or lease bandwidth from other providers? Describe the nature of these relationships?
5. How connected would you say the upstream and downstream sectors of the UK space industry are? Please give an example of this. How does this compare to other European countries?
6. The downstream service providers that you assist- how much interaction would they have with the upstream manufacturers, on the initial design stages?
7. In what form does that interaction come?
8. Are they restricted to UK manufacturers in sourcing their spectrum/data? Is it easier to deal with UK manufacturers?
9. Do you facilitate interaction between the upstream and downstream here at Harwell- in what form?
10. What are the advantages/disadvantages of companies being located in the UK?
11. Is there evidence of foreign companies relocating to the UK because of the support structure here?
12. What are the most important regulations affecting the businesses you support?
13. Have any of the companies spoken about limited spectrum being available? How have they dealt with this?
14. To what extent do these pose a barrier to entry for new firms?
15. Are you taking steps to support them?
16. How do UK space regulations differ from global and other national standards? What does this mean for your business?
17. What's distinctive about the contractual agreements relating to satellites?

18. How unique is this centre, compared to other European countries? Do you interact with these other centres?
19. Is it fair to say that there is more of a focus on the downstream sector in the UK? Why is this? Are the downstream not dependent on the upstream?
20. Why do you think the upstream and downstream companies are separated? i.e. why can't the upstream firms deliver the downstream applications?
21. Why is there an imbalance in the number of companies- so few satellite manufacturers compared to the large number of service companies? What are the implications of this for the service companies?
22. How common is freely available date for the service companies? Is this increasing? What will the implications of this be?
23. What challenges and opportunities are currently facing firms in the UK satellite industry?

Appendix 6: The Categories and Sub-Categories Used for Coding

Theme	**Categories and sub-categories**	**Coding**
Organisation	Space Geography - Orbital slots - Orbital Spectrum	O_SG - O_SG_OS - O_SG_OS
	Ground Geography - Ground Stations - Launch Sites	O_GG - O_GG_GS - O_GG_LS
	Production projects and tasks - Satellite manufacturing - Satellite operating - Applications provisions	O_PPT - O_PPT_M - O_PPT_O - O_PPT_A
	Vertical Integration	O_VI
	Upgrading	O_UP
	BSRs for Sale of a Satellite - Power of the Supplier (Manufacturer) - Power of the Buyer (Operator)	O_BSRs_S - O_BSRs_S_S - O_BSRs_S_B
	BSRS for Sale of an Application - Power of the Supplier (Operator/Reseller) - Power of the Buyer (Value-added service provider)	O_BSRs_A - O_BSRs_A_S - O_BSRs_A_B
Governance	Space as a Global Commons	G_GC
	Obtaining and orbital slot/Spectrum - Role of ITU - Role of Nation State	G_OS - G_OS_ITU - G_OS_Na
	Satellite Procurement - European Influence - UK Influence	G_SP - G_SP_E - G_SP_UK
	Satellite Insurance - Risk Management - Liability Insurance - Damage Insurance	G_SI - G_SI_R - G_SI_L - G_SI_D
	Obtaining a Space Licence - UN Treaties - Role of Nation State	G_SL - G_SL_UN - G_SL_Na
	Delivering a Satellite-enabled Application - Regulatory Barriers - European Support - National Support	G_SA - G_SA_Reg - G_SA_E - G_SA_Na
Competitiveness	UK competitiveness Vs. Global Satellite	C_UK_Vs_G

Industry	
Impact of Satellite Industry	C_Imp
Orbital slots/frequency spectrum - Access to slots/spectrum - Competitive Advantage	C_OS - C_OS_A - C_OS_Ca
Heritage - Why heritage is so important - Developing heritage - Competitive Advantage	C_H - C_H_Imp - C_H_Dev - C_H_Ca
Innovation Capability - Radical Innovation - Incremental Innovation - Competitive Advantage - The Innovation Process	C_I - C_I_RI - C_I_II - C_I_Ca - C_I_P
Networks - Networking Partners - Competitive Advantage - Network Formation	C_N - C_N_P - C_N_Ca - C_N_F
Capital - Capital Needs - Internal Profits - External Finance - Government Grants - Accessing Capital	C_C - C_C_N - C_C_P - C_C_F - C_C_G - C_C_A

LIST OF REFERENCES

Adams, D. (2004) The Changing Regulatory Environment for Speculative Housebuilding and the Construction of Core Competencies for Brownfield Development. *Environment and Planning A, 36*(4): 601-624.

Adey, P., Whitehead, M. and Williams, A.J. (2013) *From above: war, violence, and verticality*. London: C. Hurst, Publishers, Limited.

Adlen, S. (2011) *Innovation in the Global Space Industry*. MBA Dissertation, Imperial College London.

Agrawal, N., Smith, S. S., & Tsay, A. A. (2002). Multi-vendor sourcing in a retail supply chain. *Production and Operations Management*, 11: 157-182.

Agrawal, V. (2011) *Satellite technology: principles and applications*. Sussex: John Wiley & Sons.

Ajitabh, A. and Momaya, K.S. (2004) Competitiveness of firms: review of theory, frameworks and models. *Singapore management review*, 26(1): 45-61.

Aldrich, H. and Auster, E.R. (1986) Even dwarfs started small: Liabilities of age and size and their strategic implications. *Research in organizational behavior*, 8: 165-186.

Allison, A.L. (2014) *The ITU and Managing Satellite Orbital and Spectrum Resources in the 21st Century*. New York: Springer Science & Business.

Al-Rodhan, N.R. (2012) *Meta-geopolitics of Outer Space*. UK: Palgrave Macmillan.

Álvarez, I., Marin, R. and Fonfría, A. (2009) The role of networking in the competitiveness of firms. *Technological Forecasting and Social Change*, 76(3): 410-421.

Amini, S., Keasey, K. and Hudson, R. (2010) The equity funding of smaller growing companies and regional stock exchanges. *International Small Business Journal*, XX(X): 1-18.

Amin, A., & Thrift, N. (1995) Institutional issues for the European regions: from markets and plans to socioeconomics and powers of association. *Economy and society*, 24(1): 41-66.

Amos, J. (2016) Tim Peake, Brexit and the UK space sector. BBC News [online]. 16th July 2016. Available from: http://www.bbc.co.uk/news/science-environment-36805080 [Accessed 18 August 2016]

Andersen, M. and Wahlgren, B. (2015) Conference Evaluation Focusing on Learning and Transfer. *Journal of Multi-Disciplinary Evaluation*, 11(25): 34-50.

Anderson, C., Brunskill, C., Gillo, C. (2014) *Small is the new big*. [online]. Available from: https://sa.catapult.org.uk/documents/10625/98458/Small+is+the+new+Big1.2.pdf/a669be4b-0881-4e36-8958-e85e41a19792 [accessed 15 December 2015].

Ansar, A. (2012) Location decisions of large firms: analyzing the procurement of infrastructure services. *Journal of Economic Geography*: 1-22.

Ansell, C. (2000) The networked polity: Regional development in Western Europe. *Governance*, 13(2): 279-291.

Appadurai, A. (1994) "Commodities and the politics of value." In Pearce, S. M. (ed.) *Interpreting objects and collections.* London: Routledge. pp. 76-91.

Arndt, S. and Kierzkowski, H. (2001) 'Introduction'. In Arndt, S. and Kierzkowski, H. (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press. pp.1-16.

Arvanitis, S., Hollenstein, H. and Lenz, S. (2002) The effectiveness of government promotion of advanced manufacturing technologies (AMT): an economic analysis based on Swiss micro data. *Small Business Economics*, 19(4): 321-340.

Aschhoff, B. and Sofka, W. (2009) Innovation on demand- Can public procurement drive market success of innovations?. *Research Policy*, 38(8):1235-1247.

Asheim, B.T. and Isaksen, A. (2002) Regional innovation systems: the integration of local 'sticky' and global 'ubiquitous' knowledge. *The Journal of Technology Transfer*, 27(1): 77-86.

Atterton, J. (2007) The 'strength of weak ties': social networking by business owners in the Highlands and Islands of Scotland. *Sociologia Ruralis*, 47(3): 228-245.

Audretsch, D.B., Bönte, W. and Mahagaonkar, P. (2012) Financial signalling by innovative ventures: The relevance of patents and prototypes. *Research Policy*, 41(8):1407-1421.

Axelrod, Robert, and Robert O. Keohane. (1985) Achieving Cooperation Under Anarchy: Strategies and Institutions. *World Politics*, 38(1): 226-254.

Bailey, I. and Maresh, S. (2009) Scales and networks of neoliberal climate governance: the regulatory and territorial logics of European Union emissions trading. *Transactions of the Institute of British Geographers*, 34(4): 445-461.

Baimbridge, M., Cameron, S. and Dawson, P. (1996) Satellite television and the demand for football: a whole new ball game?. *Scottish Journal of Political Economy*, 43(3): 317-333.

Bair, J. (2008) Analysing economic organization: Embedded networks and global chains compared. *Economy and Society*, 37: 339-364.

Bair, J. and Palpacuer, F. (2015) CSR beyond the corporation: contested governance in global value chains. *Global Networks*, 15(1): 1-19.

Bair, J. and Peters, E.D. (2006) Global commodity chains and endogenous growth: Export dynamism and development in Mexico and Honduras. *World Development*, 34(2): 203-221.

Baldwin, R., Cave, M. and Lodge, M. (2012) *Understanding Regulation: Theory, Strategy, and Practice*. 2nd Edition. Oxford: Oxford University Press.

Balkyte, A. and Tvaronavičiene, M. (2010) Perception of competitiveness in the context of sustainable development: facets of "sustainable competitiveness". *Journal of Business Economics and Management*, 11(2): 341-365.

Barney, J.B. (1991) Firm resources and sustained competitive advantage. *Journal of Management*, 17: 99-120.

Barney, J.B., Ketchen, D.J. and Wright, M. (2011) The future of resource-based theory revitalization or decline?. *Journal of Management*, 37(5): 1299-1315.

Barnett, M. L., Jermier, J. M. and Lafferty, B. A. (2006) Corporate reputation: The definitional landscape. *Corporate Reputation Review*, 9(1): 26-38.

Barrett, L. B. (1998) Consolidators are restructuring the HVAC industry: Contractor/utility associations expand into energy services. *Strategic Planning for Energy and the Environment*, 17(3): 8-11.

Bartley, T. (2007) Institutional Emergence in An Era of Globalization: The Rise of Transnational Private Regulation of Labour and Environmental Conditions. *American Journal of Sociology* 113: 297-351.

Bathelt, H. and Cohendet, P. (2014) The creation of knowledge: local building, global accessing and economic development - toward an agenda. *Journal of Economic Geography*, 14(5): 869-882.

Bathelt, H. and Turi, P. (2011) Local, global and virtual buzz: The importance of face-to-face contact in economic interaction and possibilities to go beyond. *Geoforum*, 42(5): 520-529.

Bechhofer, F. and Paterson, L. (2012) Principles of research design in the social sciences. London: Routledge.

Becker, H. (1984) Art Worlds. Berkeley: University of California Press.

Béclard, J. (2013) With the head in the air and the feet on the ground: The EU's actorness in international space governance. *Global Governance: A Review of Multilateralism and International Organizations*, 19(3): 463-479.

Berg, B. L. (2004) *Qualitative research methods for the social sciences*. Boston: Pearson.

Beery, J. (2012) State, capital and spaceships: A terrestrial geography of space tourism. Geoforum, 43(1): 25-34.

Bennett, P. (2000) Environmental governance and private actors: enrolling insurers in international maritime regulation. Political Geography, 19(7): 875-899.

Bensaou, M. (1999) Portfolios of buyer-supplier relationships. *MIT Sloan Management* Review, 40(4):35.

Bercovitz, J. and Feldman, M. (2006) Entpreprenerial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development. The Journal of Technology Transfer, 31(1): 175-188.

BERR (2009). BERR (2009) *Summary: ONS - UK Company Statistics Reconciliation Project*. [online]. Department for Business, Enterprise and Regulatory Reform. Available from: http://www.bis.gov.uk/files/file50753.pdf [Accessed 26 August 2016]

Bessant, J., Alexander, A., Tsekouras, G., Rush, H. and Lamming, R. (2012) Developing innovation capability through learning networks. *Journal of Economic Geography*, 12(5): 1087-1112.

Beugelsdijk, S., McCann, P. and Mudambi, R. (2010) Introduction: Place, space and organization - economic geography and the multinational enterprise. *Journal of Economic Geography*, 10(4): 485-493.

Billing, C. (2013) *Heritage, Innovation and Networks as Sources of Competitiveness for Manufacturing Firms: the case of the UK Space Industry*, Masters Dissertation, University of Birmingham.

Birch, K. (2008) Alliance-driven governance: Applying a global commodity chains approach to the U.K. biotechnology industry. *Economic Geography,* 84:83–103.

BIS. (2011) *The Plan for Growth*. [online]. Department for Business Innovation and Skills. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221514/2011budget_growth.pdf. [Accessed 03 January 2016]

BIS. (2014) *Our plan for growth: science and innovation*. [online]. Department for Business Innovation and Skills. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/387780/PU1719_HMT_Science_.pdf. [Accessed 05 January 2016]

Black, J. (2001) Decentring Regulation: Understanding the Role of Regulation and Self-Regulation in a “Post-Regulatory” World. *Current Legal Problems*, 54: 103–146.

Blazek, J. (2015) Towards a typology of repositioning strategies of GVC/GPN suppliers: the case of functional upgrading and downgrading, *Journal of Economic Geography*. 1-21

Bolton, P. and Dewatripont, M. (2005) *Contract Theory*. Cambridge, MA: MIT Press.

Bontis, N. (2001) Assessing knowledge assets: a review of the models used to measure intellectual capital. *International Journal of Management Reviews*, 3(1): 41-60.

Boote, D. N. and Beile, P. (2005) Scholars before researchers: On the centrality of the dissertation literature review in research preparation. *Educational Researcher*, 34(6): 3-15.

Borggren, J., Eriksson, R.H. and Lindgren, U. (2016) Knowledge flows in high-impact firms: How does relatedness influence survival, acquisition and exit? *Journal of Economic Geography*, 16(3): 637-665.

Bormann, N. and Sheehan, M. (eds.) (2009) *Securing Outer Space: International Relations Theory and the Politics of Space*. Oxon: Routledge.

Boschma, R. and Frenken, K. (2006) Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography*, 6(3): 273-302.

Boschma, R. and Frenken, K. (2009) Some notes on institutions in evolutionary economic geography. *Economic Geography*, 85(2):151-158.

Boschma, R. and Frenken, K. (2011) The emerging empirics of evolutionary economic geography. *Journal of Economic Geography*, 11(2): 295-307.

Boschma, R. and Martin, R. (2010) *The aims and scope of evolutionary economic geography*. Cheltenham: Edward Elgar Publishing Limited.

Boyatzis, R. (1998) *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.

Boycko, M., Shleifer, A. and Vishny, R.W. (1996) A theory of privatisation. *The Economic Journal*, 106(435): 309-319.

Boyer, R. (2005) How and why capitalisms differ. *Economy and society*, 34(4): 509-557.

Brammer, S., Jackson, G. and Matten, D. (2012) Corporate social responsibility and institutional theory: New perspectives on private governance. *Socio-Economic Review*, 10(1): 3-28.

Braunschvig, David, Richard L. Garwin, and Jeremy C. Marwell. (2003) Space Diplomacy. *Foreign Affairs*, 82(4): 156-164.

Brenner, N. (2001) The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography*, 25(4): 591-614.

Bromiley, P. and Rau, D. (2016) Operations management and the resource based view: Another view. *Journal of Operations Management*, 41: 95-106.

Brown, S., Blackmon, K., Cousins, P. and Maylor, H. (2013) *Operations management: policy, practice and performance improvement*. London: Routledge.

Brülhart, M. (1998). Economic geography, industry location and trade: the evidence. *The World Economy*, 21(6): 775-801.

Bryman, A. (2012) *Social Research Methods.* 3rd Edition. Oxford: Oxford University Press.

Bryson, J. R. (1997) Obsolescence and the Process of Creative Reconstruction, *Urban Studies*, 34 (9):1439-1458.

Bryson, J.R. (2008) "Value Chains or Commodity Chains as Production Projects and Tasks: Towards a Simple Theory of Production". In Spath, D. and Ganz. W. (eds.) *The Future of Services*. Munich: Hanser.

Bryson, J.R. (2009) *Hybrid manufacturing systems and hybrid products: Services, production and industrialisation*. [online]. Studies for innovation in a modern working environment. International monitoring. Center of Learning and Knowledge Management and Department of Information Management in Mechanical Engineering, RWTH Aachen University. Available from: http://issuu.com/international_monitoring/docs/imo_bryson [Accessed 24 July 2015]

Bryson, J.R. and Taylor, M. (2010) Competitiveness by design and inimitability through service: understanding the dynamics of firm-based competition in the West Midlands jewellery and lock industries. *The Service Industries Journal*, 30(4): 583-596.

Bryson, J. R. and Rusten, G. (2011) *Design economies and the changing world economy: innovation, production and competitiveness*. London: Routledge.

Bryson, J.R., Clark, J. and Mulhall, R. (2013) *The competitiveness and evolving geography of British manufacturing: Where is manufacturing tied locally and how might this change*. [online]. Future of Manufacturing Project: Evidence Paper, 3. Foresight, Government Office for Science. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277161/ep3-geography-of-manufacturing.pdf [Accessed 29 July 2016]

Bryson, J.R. and Ronayne, M. (2014) Manufacturing carpets and technical textiles: routines, resources, capabilities, adaptation, innovation and the evolution of the British textile industry. *Cambridge Journal of Regions, Economy and Society*, 7(3): 471-488.

BT, (2011) *BT Tower says farewell to historic antennas*. BT [online], 6th December 2011. Available from: http://www.btplc.com/today/art124301.html, accessed 04/11/2015 [Accessed 12 December 2015]

Buckley, P. J., & Ghauri, P. N (2004) Globalisation, economic geography and the strategy of multinational enterprises. *Journal of International Business Studies,* 35(2): 81-98.

Bueno, E., Aragon, J.A., Paz Salmador, M. and García, V.J. (2010) Tangible slack versus intangible resources: the influence of technology slack and tacit knowledge on the capability of organisational learning to generate innovation and performance. *International Journal of Technology Management*, 49(4): 314-337.

Bulkeley, H. and Betsill, M.M. (2005) *Cities and climate change: urban sustainability and global environmental governance.* Oxon: Routledge.

Bunnell, T.G. and Coe, N.M. (2001) Spaces and scales of innovation. *Progress in Human Geography*, 25(4): 569-589.

Buss, T. F. (2001) The effect of state tax incentives on economic growth and firm location decisions: An overview of the literature. *Economic Development Quarterly*, 15(1): 90-105.

Burger, T. (1978) *Max Weber's theory of concept formation: History, laws and ideal types*. Duke University Press.

Bureau Van Dijk, (2016) *Company Report of UK Space Sector Firms*. FAME [online] Available from: http://www.bvdinfo.com/en-gb/home [Accessed 25 August 2014]

Cahill, S. (2000) Give me my space: implications for permitting national appropriation of the geostationary orbit. *Wis. Int'l LJ*, 19: 231-251.

Caiazza, R., Volpe, T. and Stanton, J.L. (2016) Global supply chain: The consolidators' role. *Operations Research Perspectives*, 3: 1-4.

Cainelli, G., Evangelista, R. and Savona, M. (2006) Innovation and economic performance in services: a firm-level analysis. *Cambridge Journal of Economics*, 30(3): 435-458.

Caniëls, M.C. and Gelderman, C.J. (2007) Power and interdependence in buyer supplier relationships: A purchasing portfolio approach. *Industrial Marketing Management*, 36(2): 219-229.

Cannon, J.P. and Homburg, C. (2001) Buyer-supplier relationships and customer firm costs. *Journal of Marketing*, 65(1): 29-43.

Cannon, J.P. and Perreault Jr, W.D. (1999) Buyer-seller relationships in business markets. *Journal of Marketing Research*, 36(4): 439-460.

Carayannis, E.G. and Provance, M. (2008) Measuring firm innovativeness: towards a composite innovation index built on firm innovative posture, propensity and performance attributes. *International Journal of Innovation and Regional Development*, 1(1): 90-107.

Caruana, A. (1997) Corporate reputation: concept and measurement. *Journal of Product & Brand Management*, 6(2): 109-118.

CASIS, (2016) *About CASIS*. CASIS [online]. Available from: http://www.iss-casis.org/About/AboutCASIS.aspx [Accessed 22 May 2016]

Castells, M. (1996), *The Rise of the Network Society*. Oxford: Basil Blackwell.

Cecere, G., Corrocher, N., Gossart, C. and Ozman, M. (2014) Lock-in and path dependence: an evolutionary approach to eco-innovations. *Journal of Evolutionary Economics*, 24(5): 1037-1065.

CGI, (2014) *Satellite Applications*. CGI [online]. Available from: https://www.cgi.com/sites/default/files/pdf/cgi-2014-annual-report.pdf, accessed 15/12/2015 [Accessed 23 April 2016]

Charles, P. (2000) "Content Analysis and Narrative Analysis". In Reis, H. T. and Judd, C.M. (eds.) *Handbook of Research Methods in Social and Personality Psychology*. Cambridge: Cambridge University Press. pp.313-323.

Chartrand, M.R. (2004) *Satellite Communications for the Nonspecialist*. Washington: Spie Press.

Chatain, O. (2011) Value creation, competition, and performance in buyer-supplier relationships. *Strategic Management Journal*, 32(1): 76-102.

Cheng, K.T. (2015) Is there a relationship between governance mechanisms and regulatory capture: the mediating effects of regulation. *International Journal of Technology, Policy and Management*, 15(4): 378-394.

Chesbrough, H., Vanhaverbeke, W. and West, J. (2006) *Open innovation: Researching a new paradigm*. Oxford: Oxford University Press.

Chesbrough, H. (2010) Business model innovation: opportunities and barriers, Long Range Planning, 43(2): 354-363.

Chikán, A. (2008) National and firm competitiveness: a general research model. *Competitiveness Review: An International Business Journal*, 18(1/2): 20-28.

Cho, M., Masui, H. and Satellite, K. (2013) Nano-satellite development project and space engineering education at Kyushu Institute of Technology. In *6th International Conference on Recent Advances in Space Technologies (RAST)*, pp. 1059-1063. (Conference Publications IEEE).

Choy, T. (2010) Air's substantiations. *Paper for Berkeley Environmental Politics Colloquium* [online]. Available from: http://globetrotter.berkeley.edu/bwep/colloquium/papers/ChoyAirEP.pdf [accessed 15 September 2015]

Christensen, J.L. and Hain, D.S. (2013) Who wants it and who gets it? A Dynamic Perspective on the Supply-Demand Nexus of External Innovation Finance [online]. In *35th DRUID Celebration Conference*. Barcelona, Spain. Available from: http://druid8.sit.aau.dk/druid/acc_papers/7ij3kf1ehfkr6sq0hd3pveh0ka7u.pdf [Accessed 6

June 2016]

Christiano, L., Eichenbaum, M. and Rebelo, S. (2009) *When is the government spending multiplier large?* [online]. National Bureau of Economic Research (No. w15394). Available from: http://www.nber.org/papers/w15394 [Accessed 8 May 2016]

Christopherson, S. and Clark, J. (2009) *Remaking Regional Economies: Power, Labor and Firm Strategies in the Knowledge Economy*. Abingdon, UK: Routledge.

Christopherson, S., & Clark, J. (2007) Power in firm networks: what it means for regional innovation systems. *Regional Studies*, 41(9): 1223-1236.

Clark, G.L. (2002) London in the European financial services industry: locational advantage and product complementarities. *Journal of Economic Geography*, 2(4): 433-453.

Clark, G.L., Gertler, M.S. and Feldman, M.P. (2003) *The Oxford Handbook of Economic Geography*. Oxford: Oxford University Press.

Clark, G.L., Lai, K.P. and Wójcik, D. (2015) Editorial Introduction to the Special Section: Deconstructing Offshore Finance. *Economic Geography*, 91(3): 237-249.

Clark, G. L., & Monk, A. H. (2014) The geography of investment management contracts: the UK, Europe, and the global financial services industry. *Environment and Planning A*, 46(3): 531-549.

Clark, G. L. and Wrigley, N. (1995) Sunk costs: a framework for economic geography. *Transactions of the institute of British geographers*, 20(2): 204-223.

Clark, J. (2013) *Working Regions: Reconnecting Innovation and Production in the Knowledge Economy*. Oxon: Routledge.

Coe, N. M. (2012) Geographies of production II A global production network A–Z. *Progress in Human Geography*, 36(3): 389-402.

Coe, N. M., Dicken, P., & Hess, M. (2008) Global production networks: realizing the potential. *Journal of Economic Geography*, *8*(3): 271-295.

Coe, N. M. and Hess, M. (2007) Global production networks: debates and challenges. In *GPERG workshop*. University of Manchester (Vol. 2526).

Coe, N. M., Hess, M., Yeung, H. W. C., Dicken, P., and Henderson, J. (2004) "Globalizing" regional development: A global production networks perspective. *Transactions of the Institute of British Geographers*, 29:468–84.

Coe, N.M., Lai, K.P. and Wójcik, D. (2014) Integrating finance into global production networks. *Regional Studies*, 48(5): 761-777.

Coen, D. and Thatcher, M. (2008) Network governance and multi-level delegation: European networks of regulatory agencies. *Journal of Public Policy*, 28(01): 49-71.

Collinge, C. (1999). Self-organisation of society by scale: a spatial reworking of regulation theory. *Environment and planning D: Society and Space*, 17(5): 557-574.

Collins, C. J. and Clark, K. D. (2003) Strategic human resource practices, top management team social networks, and firm performance: The role of human resource practices in creating organizational competitive advantage. *Academy of management Journal*, 46(6): 740-751.

Collis, C. (2009) The geostationary orbit: a critical legal geography of space's most valuable real estate. *The Sociological Review*, 57(1): 47-65.

Collis, C. and Graham, P. (2009) Political geographies of Mars: A history of Martian management. *Management & Organizational History*, 4(3): 247-261.

Cooke, P. and Morgan, K. (1993) The network paradigm: new departures in corporate and regional development. *Environment and planning D: Society and Space*, 11(5): 543-564.

Cooper, R., & Fox, S. (1990) The ‘texture ‘of organizing. *Journal of Management Studies*, *27*(6): 575-582.

Cope, M., 2010. “Coding Transcripts and Diaries”. In Clifford, N., French, S. and Valentine, G. (eds.) *Key Methods in Geography*. 2nd Edition. pp.440-451.
Copiz, A. (2001) Scarcity in space: the international regulation of satellites. *CommLaw Conspectus*, 10: 207-227.

Corsini, A., Farina, P., Antonello, G., Barbieri, M., Casagli, N., Coren, F., Guerri, L., Ronchetti, F., Sterzai, P. and Tarchi, D. (2006) Space-borne and ground-based SAR interferometry as tools for landslide hazard management in civil protection. *International Journal of Remote Sensing*, 27(12): 2351-2369.

Corsten, D. and Felde, J. (2005) Exploring the performance effects of key-supplier collaboration: an empirical investigation into Swiss buyer-supplier relationships. *International Journal of Physical Distribution & Logistics Management*, 35(6): 445-461.

Coulson, A. and Ferrario, C (2007) ‘Institutional thickness’: local governance and economic development in Birmingham, England. *International Journal of Urban and Regional Research*, 31(3): 591-615.

Cox, A. (2001) Managing with power: strategies for improving value appropriation from supply relationships. *Journal of Supply Chain Management*, 37(1): 42-47.

CPNI, (2016) *The National Infrastructure*, CPNI [online]. Available from: https://www.cpni.gov.uk/about/cni/ [Accessed 28 January 2016]

Crabtree, B.F. and Miller, W.L. (eds.) (1999) *Doing qualitative research*. London: Sage Publications.

Crafts, N. and Wolf, N. (2014) The location of the UK cotton textiles industry in 1838: A quantitative analysis. *The Journal of Economic History*, 74(04): 1103-1139.

Creswell, J.W. (1994) *Research design: Qualitative and quantitative*. London: Sage Publications.

Crow, G., Wiles, R., Heath, S. and Charles, V. (2006) Research ethics and data quality: The implications of informed consent. *International Journal of Social Research Methodology*, 9(2): 83-95.

Cumbers, A., MacKinnon, D. and McMaster, R. (2003) Institutions, Power and Space Assessing the Limits to Institutionalism in Economic Geography. *European Urban and Regional Studies*, 10(4): 325-342.

Dahlander, L. and Gann, D.M. (2010) How open is innovation?. *Research Policy*, 39(6): 699-709.

Damanpour, F., Walker, R.M. and Avellaneda, C.N. (2009) Combinative effects of innovation types and organizational performance: A longitudinal study of service organizations. *Journal of Management Studies*, 46(4): 650-675.

Daniels, P., Rubalcaba, L., Stare, M. and Bryson, J. (2011) How many Europes? Varieties of capitalism, divergence and convergence and the transformation of the European services landscape. *Tijdschrift voor economische en sociale geografie*, 102(2): 146-161.

David, P. A. (1994) Why are institutions the 'carriers of history'?: Path dependence and the evolution of conventions, organizations and institutions. *Structural change and economic dynamics*, 5(2): 205-220.

David, P.A., Hall, B.H. and Toole, A.A. (2000) Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, 29(4): 497-529.

Davies, A. (2004) Moving base into high-value integrated solutions: a value stream approach. *Industrial and Corporate Change*, 13(5): 727-756.

Davies, A.R. and Mullin, S.J. (2011) Greening the economy: interrogating sustainability innovations beyond the mainstream. *Journal of Economic Geography*, 11(5): 793-816.

De Vaan, M., Boschma, R. and Frenken, K. (2012) Clustering and firm performance in project-based industries: the case of the global video game industry, 1972–2007. *Journal of Economic Geography*. 1-22.

De Vaus, D.A. (2001) *Research Design in Social Research*, London: Sage Publications.

Denscombe, M. (2002) *Ground Rules for Good Research, a 10 point guide for social researchers.* Buckingham: Open University Press.

De Rassenfosse, G. (2012) How SMEs exploit their intellectual property assets: evidence from survey data, *Small Business Economics,* 39(2): 437-452.

Diamond, J. (1997) *Guns, Germs and Steel*. New York: WW Norton.

Dicken, P. (1992) International production in a volatile regulatory environment: the influence of national regulatory policies on the spatial strategies of transnational corporations. *Geoforum*, 23(3): 303-316.

Dicken, P. (2003) *Global Shift: Reshaping the Global Economic Map in the 21st Century*. California: Sage Publications.

Dicken, P. (2006) "Foreword". In Bagchi-Sen, S. and Smith, H.L. (eds.) *Economic Geography. Past, present and future*. p.14

Dicken, P., Kelly, P. F., Olds, K., & Wai-Chung Yeung, H. (2001) Chains and networks, territories and scales: towards a relational framework for analysing the global economy. *Global networks*, 1(2): 89-112.

Dixon, A. D. (2011) Variegated capitalism and the geography of finance: towards a common agenda. *Progress in Human Geography*, 35(2): 193-210.

Dixon, A .D. (2011b) The geography of finance: form and functions. *Geography Compass*, 5(11): 851-862.

Dodds, K. (2010) Flag planting and finger pointing: The Law of the Sea, the Arctic and the political geographies of the outer continental shelf. *Political Geography*, 29(2): pp.63-73.

Dögl, C., Holtbrügge, D. and Schuster, T. (2012) Competitive advantage of German renewable energy firms in India and China: An empirical study based on Porter's diamond. *International Journal of Emerging Markets*, 7(2): 191-214.

Dolman, E.C. (2002) *Astropolitik: classical geopolitics in the space age*. Volume 4. London: Frank Cass Publishers.

Dubois, A. (2015) Business networks and the competitiveness of small manufacturing firms in Sweden's northern periphery. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography*, 69(3): 135-151.

Duffy, R.S. (2008) Towards a better understanding of partnership attributes: An exploratory analysis of relationship type classification. *Industrial Marketing Management*, 37(2): 228-244

Dunning, J. H. (1993) Internationalizing Porter's diamond. *Management International Review*, 2: 7-15.

Dupuy, C., Lavigne, S. and Nicet-Chenaf, D. (2010) Does geography still matter? Evidence on the portfolio turnover of large equity investors and varieties of capitalism. *Economic Geography*, 86(1): 75-98.

Dunsire, A. (1993) “Modes of governance”. In Kooiman, J. (ed.) *Modern Governance. New Government-Society Interactions*. London: Sage. pp.21-34.

Elden, S. (2013) Secure the volume: vertical geopolitics and the depth of power. *Political Geography*, 34: 35-51.

Eling, M. and Marek, S.D. (2014) Corporate governance and risk taking: Evidence from the UK and German insurance markets. *Journal of Risk and Insurance*, 81(3): 653-682.

Ellis, N. (2010) *Business to business marketing: Relationships, networks and strategies*. Oxford: Oxford University Press.

Eneberg, J. (2016) *Satellite Role in 5G* [online]. Available from: file:///C:/Users/chloe/Downloads/Jonas_Eneberg_-_Inmarsat_-_Satellite_Role_in_5G.pdf [Accessed 22 September 2016]

ERA, (2016) About Juste Retour. ERA [online]. Available from: https://www.era-learn.eu/service/glossary/juste-retour [Accessed 01 October 2015]

Eriksson, P. and Kovalainen, A. (2015) *Qualitative Methods in Business Research: A Practical Guide to Social Research*. London: Sage Publications.

Ernst, D. and Kim, L. (2002) Global production networks, knowledge diffusion, and local capability formation. *Research policy*, 31(8): 1417-1429.

ESA (2013) *Satellite Frequency Bands* [online]. Available from: http://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/Satellite_frequency_bands [Accessed 23 June 2016]

ESA (2015) *Galileo Satellites* [online]. Available from: http://www.esa.int/Our_Activities/Navigation/Galileo/Launching_Galileo/And_yet_it_moves_14_Galileo_satellites_now_in_orbit [Accessed 02 February 2016]

ESA (2015b) *Sustainable Fishing by Satellite* [online]. Available from: http://www.esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/Oceans/Sustainable_fishing_by_satellite [Accessed 02 February 2016]

ESA, (2016*) Industrial policy and geographical distributions* [online]. Available from: http://www.esa.int/About_Us/Business_with_ESA/How_to_do/Industrial_policy_and_geographical_distribution [Accessed 02 February 2016]

ESA, (2016b) *Earth observation- satellites* [online]. Available from: http://www.esa.int/SPECIALS/Eduspace_EN/SEM7YN6SXIG_0.html [Accessed 02 February 2016]

ESOA, (2010) *Types of Spectrum* [online]. Available from: https://www.esoa.net/upload/files/policy/spectrum_brochure_summit.pdf 2010 [Accessed 02 February 2016]

Essletzbichler, J. and Rigby, D.L. (2007) Exploring evolutionary economic geographies. *Journal of Economic Geography*. 7: 549-571.

ESRC, (2015) *Framework for research ethics* [online]. Available from: http://www.esrc.ac.uk/files/funding/guidance-for-applicants/esrc-framework-for-research-ethics-2015/ [Accessed 07 July 2016]

Ettlie, J. E., Bridges, W. P. and O'Keefe, R. D. (1984) Organization strategy and structural differences for radical versus incremental innovation, *Management Science*, 30(6): 682-695.

Eurconsult, (2015) *Euroconsult forecasts increase in satellite launches* [online]. Available from: http://www.parabolicarc.com/2015/08/26/euroconsult-satellite-predictions/ [Accessed 02 February 2016]

European Commission, (2016) *Public procurement* [online]. Available from: http://ec.europa.eu/growth/single-market/public-procurement/index_en.htm [Accessed 02 February 2016]

FAA, (2013) *Commercial Space Transportation Forecasts* [online]. Available from: https://www.faa.gov/about/office_org/headquarters_offices/ast/media/2013_GSO_NGSO_Forecast_Report_June.pdf [Accessed 23 June 2016]

Fahy, J. (2002) A resource-based analysis of sustainable competitive advantage in a global environment. *International Business Review*, 11(1): 57-77.

Fairchild, A. (2003) Possible disintermediation: What role for banks in electronic invoicing (EIPP)?. In 16th *Bled eCommerce Conference*. Bled, Slovenia. pp.107-118. (Conference Publication).

Falkner, R. (2003) Private environmental governance and international relations: exploring the links. *Global Environmental Politics*, 3(2): 72-87.

Fereday, J. and Muir-Cochrane, E. (2006) Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International journal of qualitative methods*, 5(1): 80-92.

Fineman, S. and Hosking, D. (1990) Editorial, *Journal of Management Studies*, 27(6), pp.573-574

Finger, M. and Varone, F. (2006) Governance of network industries: towards European regulators, differentiated regulations, or self-regulation?. In *European Consortium for Political Research Standing Group on Regulatory Governance Conference*, University of Bath, Bath. pp.7-8. (Conference Publications).

Finney, R. Z., Lueg, J. E. and Campbell, N. D. (2008) Market pioneers, late movers, and the resource-based view (RBV): A conceptual model. *Journal of Business Research*, 61(9): 925-932.

Fitjar, R.D. and Huber, F. (2014). Global pipelines for innovation: insights from the case of Norway. *Journal of Economic Geography*: 1-23.

Fombrun, C. and Van Riel, C. (1997) The reputational landscape. *Corporate Reputation Review*. 1-16.

Fortescue, P., Swinerd, G. and Stark, J. (eds.). (2011) *Spacecraft systems engineering*. Suusex: John Wiley & Sons.

Foxon, T. and Pearson. P (2008) Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. *Journal of Clean Production*, 16(1):148-161

Fransman, M. (2002) Mapping the evolving telecoms industry: the uses and shortcomings of the layer model. *Telecommunications Policy*, 26(9): 473-483.

Freel, M.S. (200) Are small innovators credit rationed?. *Small Business Economics*, 28(1): 23-35.

Frenken, K. and Boschma, R. A. (2007) A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography*. 1-15.

Fritsch, M. and Slavtchev, V. (2007) Universities and innovation in space. *Industry and Innovation*, 14(2): 201-218.

Hollinger, P. (2016) UK space sector fears Brexit will hinder EU contract bids. *Financial Times* [online], August 14th 2016. Available from: http://www.ft.com/cms/s/0/48e12b28-5e2d-11e6-bb77-a121aa8abd95.html [Accessed 14 August 2016]

Fujita M, Krugman PR, Venables A.J. (1999) *The Spatial Economy: Cities, Regions and International Trade*. Boston: MIT Press.

Fujita, M. and Mori, T. (2005) Frontiers of the New Economic Geography. *Papers in Regional Science*, 84(3): 377-405.

Galbreath, J. (2005) Which resources matter the most to firm success? An exploratory study of resource-based theory. *Technovation*, 25(9): 979-987.

GAO (2011) *Telecommunications- Competition, Capacity and Costs in the Fixed Satellite Services Industry* [online]. Available from: http://www.gao.gov/products/GAO-11-777 [Accessed 19 May 2016]

George, A. and Lane, N. (2005) *United States Space Policy: Challenges and Opportunities*. Cambridge, MA: American Academy of Arts and Science.

Gereffi, G. (1994) The Organization of Buyer-Driven Global Commodity Chains: How US Retailers Shape Overseas Production Networks. *Commodity Chains and Global Capitalism*. 95-122.

Gereffi, G. (2014) Global value chains in a post-Washington Consensus world. *Review of International Political Economy*, 21(1): 9-37.

Gereffi, G., Humphrey, J. and Sturgeon, T. (2005) The governance of global value chains. *Review of international political economy*, 12(1): 78-104.

Gereffi, G. and Mayer, F. (2006) Globalization and the Demand for Governance. In *ILO Social Policy Lectures. The new offshoring of jobs and global development.* Geneva. pp.39-58 (Lecture Publication).

Gereffi, G. and Lee, J. (2014) Economic and social upgrading in global value chains and industrial clusters: Why governance matters. *Journal of Business Ethics*. 1-14.

German, A. (2014) *Measuring the effectiveness of innovation clusters as a means of delivering the UK Government's growth strategy*. MBA Dissertation, Portsmouth Business School.

Gershon, R. A. (2009) *Telecommunications and Business Strategy*. Oxon: Routledge.

Gertler, M. S. (2003) Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there). *Journal of economic geography*, 3(1): 75-99.

Gerson, K. and Horowitz, R. (2002) "Observation and interviewing: Options and choices in qualitative research". In May, T. (ed.) Qualitative Research in Action. London: Sage Publications. pp.199-224.

Gherardi, S. and Strati, A. (1990) The 'Texture' of Organizing in an Italian University Department. *Journal of Management Studies,* 27(6): 605-618.

Gibbon, P., Bair, J. and Ponte, S. (2008) Governing global value chains: an introduction. *Economy and Society*, 37(3): 315-338.

Giudici, G. and Paleari, S. (2000) The provision of finance to innovation: a survey conducted among Italian technology-based small firms. *Small Business Economics,* 14(1): 37-53.

Golafshani, N. (2003) Understanding reliability and validity in qualitative research. *The Qualitative Report*, 8(4): 597-606.

Gorard, S. (2013) *Research Design. Creating Robust Approaches for the Social Sciences*. London: Sage Publications.

Gov.uk, (2014) Innovation Growth Strategy. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298362/igs-action-plan.pdf [Accessed 12 September 2015]

Gov.UK. (2015), *National Space Security Policy.* [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307346/National_Space_Security_Policy.pdf [Accessed 06 June 2016].

Gov.UK. (2015b) *National Space Policy.* [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/484865/NSP_-_Final.pdf [Accessed 03 December 2015].

Grabosky, P. (2013) Beyond Responsive Regulation: The expanding role of non-state actors in the regulatory process. *Regulation & Governance*, 7(1): 114-123.

Graham, S. and Hewitt, L. (2013) Getting off the ground. On the politics of urban verticality. *Progress in Human Geography*, 37(1): 72-92.

Granovetter, M.S. (1973) The strength of weak ties. *American journal of sociology*. 1360-1380.

Griffin, L. (2008) The North Sea fisheries crisis and good governance. *Geography Compass*, 2(2): 452-475.

Griffiths, A. and Zammuto, R. F. (2005) Institutional governance systems and variations in national competitive advantage: An integrative framework. *Academy of Management Review*, 30(4): 823-842.

Grimard, M. (2012) *Economical Sustainability of the Space Value Chain: Role of Government, Industry and Private Investors*. [online]. Available from: http://iislweb.org/docs/2012_Grimard.pdf [Accessed 15 December 2016]

Groenleer, M., Kaeding, M. and Versluis, E. (2010) Regulatory governance through agencies of the European Union? The role of the European agencies for maritime and aviation safety in the implementation of European transport legislation. *Journal of European Public Policy*, 17(8): 1212-1230.

Gruber, H. and Verboven, F. (2001) The evolution of markets under entry and standards regulation- the case of global mobile telecommunications. *International Journal of Industrial Organization,* 19(7): 1189-1212.

G-Step (2015) *Project Information* [online]. Available from: http://www2.le.ac.uk/projects/g-step/info [Accessed 22 May 2016]

Guillemin, M. and Gillam, L. (2004) Ethics, reflexivity, and “ethically important moments” in research. *Qualitative Inquiry*, 10(2): 261-280.

Gulbrandsen, L.H. (2004) Overlapping public and private governance: Can forest certification fill the gaps in the global forest regime?. *Global Environmental Politics*, 4(2): 75-99.

Guy, C.M. (1997) Fixed assets or sunk costs? An examination of retailers' land and property investment in the United Kingdom. *Environment and Planning A*, 29(8): 1449-1464.

Haanes, K. and Fjeldstad, O. (2000) Linking intangible resources and competition. *European Management Journal*, 18(1): 52-62.

Haberly, D. and Wójcik, D. (2015) Regional blocks and imperial legacies: Mapping the global offshore FDI network. *Economic Geography*, 91(3): 251-280.

Hakansson, H. and Snehota, I. (eds.) (1995) *Developing relationships in business networks*. London: Routledge.

Hall, R. (1993) A framework linking intangible resources and capabilities to sustainable competitive advantage. *Strategic Management Journal*, 14(8): 607-618.

Hall, P.A. and Soskice, D. (eds.) (2001) *Varieties of capitalism: The institutional foundations of comparative advantage*. Oxford: Oxford University Press.

Hansen, M.T. (2002) Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organization Science*, 13(3): 232-248.

Hansen, U. E., Fold, N. and Hansen, T. (2014) Upgrading to lead firm position via international acquisition: learning from the global biomass power plant industry. *Journal of Economic Geography*. 1-23.

Hanson, A., & Rohlin, S. (2011) Do Location-based Tax Incentives Attract New Business Establishments. *Journal of Regional Science*, 51(3): 427-449.

Hanson, G.H., Mataloni Jr, R.J. and Slaughter, M.J. (2005) Vertical production networks in multinational firms. *Review of Economics and Statistics*, 87(4): 664-678.

Harrington, C., Curtis, A. and Black, R. (2008) Locating communities in natural resource management. *Journal of Environmental Policy and Planning*, 10: 199-215.

Harris, R. and Baumann, I. (2015) Open data policies and satellite Earth observation. *Space Policy*, 32: 44-53.

Harrison, G.J. (2012) The Commercial Space Industry and Launch Market. *Journal of Magnetohydrodynamics and Plasma Research*, 17(3): 183-193.

Harrison, R.T. and Mason, C.M. (1992) International perspectives on the supply of informal venture capital. *Journal of Business Venturing*, 7(6): 459-475.

Harvey, D. (2014). *Seventeen Contradictions and the End of Capitalism*. Oxford: Oxford University Press.

Hawkins, B. and Holden, C. (2014) 'Water dripping on stone'? Industry lobbying and UK alcohol policy. *Policy & Politics*, 42(1): 55-70.

Hellmann, T. and Puri, M. (2000) The interaction between product market and financing strategy: The role of venture capital. *Review of Financial studies*,13(4): 959-984.

Helper, S.R. and Sako, M. (1995) Supplier relations in Japan and the United States: are they converging?. Sloan Management Review, 36(3):77-85.

Henderson, J., Dicken, P., Hess, M., Coe, N. and Yeung, H. W. C. (2002) Global production networks and the analysis of economic development. *Review of international political economy*, 9(3): 436-464.

Henn, S. and Bathelt, H. (2015) Knowledge generation and field reproduction in temporary clusters and the role of business conferences. *Geoforum*, 58: 104-113.

Herod, A. (1999) "Reflection on interviewing foreign elites: praxis, positionality, validity and the cult of the 'insider'", *Geoforum*, 30(4): 313-27

Hervas-Oliver, J.L. and Albors-Garrigos, J. (2009) The role of the firm's internal and relational capabilities in clusters: when distance and embeddedness are not enough to explain innovation. *Journal of Economic Geography*, 9(2): 263-283.

Hewitt, L. and Graham, S. (2015). Vertical cities: Representations of urban verticality in 20th-century science fiction literature. *Urban Studies*, 52(5): 923-937.

Hill, E., Wial, H. and Wolman, H. (2008) *Exploring regional economic resilience*, Institute of Urban and Regional Development, Working Paper. Available from: http://escholarship.org/uc/item/7fq4n2cv [Accessed 23 April 2016]

Holmes, T. J. (1998) The effect of state policies on the location of manufacturing: Evidence from state borders. *Journal of Political Economy*, 106(4): 667-705.

Holstein, J. and Gubrium, J. (2004) "The Active interview". In Silverman, D. (ed.) *Qualitative Research: Theory, Method and Practice.* 3rd Edition. London: Sage Publications.

Hölzl, W. (2005) *The evolutionary theory of the firm. Routines, complexity and change*. [online]. Available from: http://epub.wu.ac.at/1650/ [Accessed 23 April 2016]

Hooghe, L. and Marks, G. (2001) *Types of multi-level governance*. European Integration Online Papers (EIoP).

Hooley, G., Broderick, A. and Möller, K. (1998) Competitive positioning and the resource-based view of the firm. *Journal of strategic marketing*, 6(2): 97-116.

Hopkins, T.K. and Wallerstein, I. (1986) Commodity chains in the world-economy prior to 1800. *Review (Fernand Braudel Center)*, 10(1): 157-170.

Hottes, K. (1993) “Submarine Cables in Our Times Competition between Sea cables and Satellites”. In Bakis, H., Abler, R. and Roche, E.M. (eds.) *Corporate Networks, international telecommunications and interdependence: perspectives from geography and information systems*. London: Belhaven, pp.99-110.

Howells, J. R. (2002) Tacit knowledge, innovation and economic geography. *Urban Studies*, 39(5-6): 871-884.

Howells, J., Ramlogan, R. and Cheng, S. L. (2012) Universities in open innovation system: A UK perspective. *International Journal of Entrepreneurial Behaviour and Research*, 18(4): 440-456.

Howells, J. and Roberts, J. (2000) From Innovation Systems to Knowledge Systems. *Prometheus,* 18(1): 17-31.

Hughes, A., Wrigley, N. and Buttle, M. (2008) Global production networks, ethical campaigning, and the embeddedness of responsible governance. *Journal of Economic Geography*, *8*(3): 345-367.

IOD, (2012) *The UK Space Economy: The Present and Exciting Future* [online]. Available from: http://www.iod.com/MainWebSite/Resources/Document/the_uk_space_economy_the_present_and_exciting_future.pdf, accessed 01/08/2013 [Accessed 2 February 2016]

Ireson, A. (ed.) (2000) *City Levels*. Basel: Birkhauser.

Ireland, R.D. and Webb, J.W. (2007) Strategic entrepreneurship: Creating competitive advantage through streams of innovation. *Business Horizons*, 50(1): 49-59.

Irvine, A., Drew, P. and Sainsbury, R. (2013) ‘Am I not answering your questions properly?’Clarification, adequacy and responsiveness in semi-structured telephone and face-to-face interviews. *Qualitative Research*, 13(1): 87-106.

Isaksen, A. (2014) Industrial development in thin regions: trapped in path extension? *Journal of Economic Geography*. 1-16.

ISSUU. (2016) *UK Space Directory*. [online]. Available from: https://issuu.com/benham/docs/space_directory-issuu [Accessed 19 May 2016]

ITAR, (2016) *ITAR Regulations* [online]. Available from: https://www.pmddtc.state.gov/regulations_laws/itar.html [Accessed 06 June 2016]

ITU, (2016) *About ITU* [online]. Available from: http://www.itu.int/en/about/Pages/default.aspx [Accessed 08 February 2016]

Ivarsson, I. and Alvstam, C.G. (2010) Upgrading in global value-chains: a case study of technology-learning among IKEA-suppliers in China and Southeast Asia. *Journal of Economic Geography*. 1-22.

James, S. D., Leiblein, M. J. and Lu, S. (2013) How Firms Capture Value from their Innovations. *Journal of management*, 39(5): 1123-1155.

Jenkins, M. and Tallman, S. (2015) The Geography of Learning: Ferrari Gestione Sportiva 1929–2008. *Journal of Economic Geography*. 1-24.

Jensen, S.H., Poulfelt, F. and Kraus, S. (2010) Managerial routines in professional service firms: transforming knowledge into competitive advantages. *The Service Industries Journal*, 30(12): 2045-2062.

Jeppesen, T., List, J.A. and Folmer, H. (2002) Environmental regulations and new plant location decisions: evidence from a meta-analysis. *Journal of Regional Science*, 42(1): 19-49.

Jessop, B. (2004) "Multi-level governance and multi-level metagovernance". In Bache, I. and Flinders, M. (eds.) *Multi-level governance*. Oxford: Oxford University Press. pp.49-74.

Jessop, B. (2005) The Political Economy Of Scale And European Governance. *Tijdschrift voor Economische en Sociale Geografie*, 96(2): 225-230.

Jessop, B. (2011) Metagovernance. In Bevir, M. (ed.) *The Sage Handbook of Governance*, Thousand Oaks, CA: Sage. pp.106–123.

John, C.H. and Pouder, R.W. (2006) Technology clusters versus industry clusters: resources, networks, and regional advantages. *Growth and Change*, 37(2): 141-171.

Johnson, S.B. (2007) The Political Economy of Spaceflight. In Dick, S.J. (ed.) *Societal Impact of Spaceflight*. Washington: National Aeronautics and Space Administration Office of External Relations. pp.141-191.

Johnson, W.C. and Sohl, J. (2012) Angels and venture capitalists in the initial public offering market. *Venture Capital*, 14(1): 27-42.

Jones, A. (2005) Truly global corporations? Theorizing 'organizational globalization' in advanced business-services. *Journal of Economic Geography*, 5(2): 177-200.

Jones, A. (2008) Beyond embeddedness: economic practices and the invisible dimensions of transnational business activity. *Progress in Human Geography*, 32(1): 71-88.

Jones, A. (2014) Geographies of production I Relationality revisited and the 'practice shift' in economic geography. *Progress in Human Geography*, 38(4): 605-615.

Jones, O. and Craven, M. (2001) Expanding capabilities in a mature manufacturing firm: absorptive capacity and the TCS. *International Small Business Journal*, 19(3): 39-55.

JSAT International, (2014) *Components of a satellite* [online]. Available from: http://www.jsati.com/news.asp [Accessed 15 December 2015].

Kidder, S. and Vonder Haar, T.H. (2014) *A Satellite constellation to observe the spectral radiance shell of Earth* [online]. Available from: https://pdfs.semanticscholar.org/3d9e/e105a89afde06e0b85b7f9e2c24261aa6e58.pdf [Accessed 22 September 2016]

Keeble, D., Lawson, C., Moore, B. and Wilkinson, F. (1999) Collective learning processes, networking and 'institutional thickness' in the Cambridge region. *Regional Studies*, 33(4): 319-332.

Kennedy, M.S., Ferrell, L.K. and LeClair, D.T. (2001) Consumers' trust of salesperson and manufacturer: an empirical study. *Journal of Business Research*, 51(1): 73-86.

Kessler, E. H., Bierly, P. E. and Gopalakrishnan, S. (2000) Internal vs. external learning in new product development: effects on speed, costs and competitive advantage, *R&D Management*, 30(3): 213-224.

Kheder, S.B. and Zugravu, N. (2012) Environmental regulation and French firms location abroad: An economic geography model in an international comparative study. *Ecological Economics*, 77: 48-61.

Kidd, C. (2010) From observations to forecasts- Part 3. Key principles and recent developments in satellite observations. *Weather*, 65(1): 3-9.

Kim, K.K., Ryoo, S.Y. and Jung, M.D. (2011) Inter-organizational information systems visibility in buyer–supplier relationships: the case of telecommunication equipment component manufacturing industry. *Omega*, 39(6): 667-676.

Kingsley, G. and Malecki, E. J. (2004) Networking for competitiveness, *Small Business Economics*, 23(1): 71-84.

Kitchin, R. and Tate, N, J. (2000) *Conducting Research into Human Geography: theory, methodology and practice*. Essex: Pearson.

Kitson, M., Martin, R. and Tyler, P. (2004) Regional competitiveness: an elusive yet key concept?. *Regional Studies*, 38(9): 991-999.

Kitson, M., Martin, R. and Tyler, P. (2005) *The Regional Competitiveness Debate*. The Cambridge-MIT Institute [online]. Available from: https://www.researchgate.net/profile/Ron_Martin3/publication/265248371_THE_REGIONAL_COMPETITIVENESS_DEBATE/links/54f052020cf2432ba65a14a6.pdf [Accessed 07 July 2016]

Knight, E.R. (2011) The economic geography of European carbon market trading. *Journal of Economic Geography*, 11(5): 817-841.

Knoben, J. (2011) The geographic distance of relocation search: an extended resource-based perspective. *Economic Geography*, 87(4): 371-392.

Kolawole, M. O. (2013). *Satellite communication engineering*. 2nd Edition. Boca Raton, Florida: CRC Press.

Kolovos, A. (2002) Why Europe needs space as part of its security and defence policy. *Space Policy*, 18(4): 257-261.

Kontopoulos, K.M. (2006) *The Logics of Social Structure*. Volume. Cambridge: Cambridge University Press.

Kooiman, J. and Van Vliet, M. (2000) Self-governance as a mode of societal governance. *Public Management an International Journal of Research and Theory*, 2(3): 359-378.

Kraay, A. (2010) *How Large is the Government Spending Multiplier? Evidence from World Bank Lending.* World Bank Policy Research Working Paper Series. Available from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1726249 [Accessed 02 November 2016]

Krugman, P. (1993). First nature, second nature, and metropolitan location. *Journal of Regional Science*, 33(2): 129-144.

Kunstadter, C. (2014) *World Space Risk Forum* [online]. Available from: http://seradata.com/SSI/2014/05/world-space-risk-forum-2014-review-and-sketch-insurers-fret-about-falling-into-loss/ [Accessed 15 September 2015]

La Rocca, M., La Rocca, T. and Cariola, A. (2011) Capital structure decisions during a firm's life cycle. *Small Business Economics*, 37(1): 107-130.

Lager, T., & Rennard, J. P. (2014) Managing the manufacturing- R&D interface: an extended editorial viewpoint. *Journal of Manufacturing Technology Management*, 25(2): 146-154.

Lahcen, A. (2015) Space Policy. In *ESPI Autumn Conference "the governance of space"*. Vienna. [online]. Available from: http://www.espi.or.at/News-Archive/review-of-the-espi-autumn-conference-the-governance-of-space-published-in-space-policy [Accessed 15 September 2015]

Lane, C. and Probert, P. (2004) Between the global and the local: a comparison of the German and UK clothing industry, *Competition and Change*, 8: 243–266.

Launius, R. D. (2002) "Historical Dimensions of the Space Age." In Sadeh, E. (ed.) *Space Politics and Policy: An Evolutionary Perspective*. London: Kluwer Academic Publishers. pp.3-25.

Laursen, K. and Salter, A. (2006) Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, 27(2): 131-150.

Lazzarini, S., Chaddad, F. and Cook, M. (2001) Integrating supply chain and network analyses: the study of netchains. *Journal on Chain and Network Science,* 1(1): 7-22.

Lechner, W. and Baumann, S. (2000) Global navigation satellite systems. *Computers and Electronics in Agriculture,* 25(1): 67-85.

Lee, J. and Gereffi, G. (2015) Global value chains, rising power firms and economic and social upgrading. *Critical Perspectives on International Business*, 11(3/4): 319-339.

Lee, N. and Brown, R. (2016) Innovation, SMEs and the liability of distance: the demand and supply of bank funding in UK peripheral regions. *Journal of Economic Geography*: 1-28.

Legard, R., Keegan, J., Ward, K (2013) "In-depth Interviews". In Ritchie, J. and Lewis, J. (eds.) *Qualitative Research Practice. A Guide for Social Science Students*. London: Sage Publications. pp.139- 165.

Lengnick-Hall, C. A. (1992) Innovation and competitive advantage: what we know and what we need to learn, *Journal of Management*, 18(2): 399-429.

Levi-Faur, D. (ed.) (2012). *The Oxford Handbook of Governance*. Oxford: Oxford University Press.

Lewis, N., Moran, W., Perrier-Cornet, P. and Barker, J. (2002) Territoriality, enterprise and réglementation in industry governance. *Progress in Human Geography,* 26(4): 433-462.

LinkedIn. (2016) *LinkedIn Home Page* [online]. Available from: https://www.linkedin.com/home?trk=nav_responsive_tab_home [Accessed 05 May 2016]

LinkedIn. (2016) *Connections- overview* [online]. Available from: https://www.linkedin.com/help/linkedin/answer/15495/connections-overview?lang=en [Accessed 25 September 2016]

List, J.A. and Co, C.Y. (2000) The effects of environmental regulations on foreign direct investment. *Journal of Environmental Economics and Management,* 40(1): 1-20.

List, J.A. and McHone, W.W. (2000) Measuring the effects of air quality regulations on "dirty" firm births: evidence from the neo-and mature-regulatory periods. *Papers in Regional Science,* 79(2): 177-190.

Little, J., Ilbery, B., Watts, D., Gilg, A. and Simpson, S. (2012) Regionalization and the rescaling of agro-food governance: Case study evidence from two English regions. *Political Geography,* 31(2): 83-93.

Livingston, D. (1992) *The geographical tradition: episodes in the history of a contested enterprise*. Oxford: Blackwell.

Lobel, L. (2012) “New Governance as Regulatory Governance”; In Levi-Faur, D. (ed.) *The Oxford Handbook of Governance*. Oxford: Oxford University Press. pp.65-83.

Loorbach, D. (2010) Transition management for sustainable development: a prescriptive, complexity-based governance framework. *Governance*, 23(1): 161-183.

London Economics, (2015) *The Case for Space 2015. The impact of space on the UK economy*. [online]. Available from: http://www.ukspace.org/wp-content/uploads/2015/07/LE-Case-for-Space-2015-Full-Report.pdf [Accessed 15 December 2015]

Lorenzen, M. and Mudambi, R. (2012) Clusters, connectivity and catch-up: Bollywood and Bangalore in the global economy. *Journal of Economic Geography*. 1-34.

Love, J.H., Roper, S. and Bryson, J.R. (2011) Openness, knowledge, innovation and growth in UK business services. *Research Policy*, 40(10): 1438-1452.

Lüthi, S., Thierstein, A. and Goebel, V. (2010) Intra-firm and extra-firm linkages in the knowledge economy: the case of the emerging mega-city region of Munich. *Global Networks*, 10(1): 114-137

MacDonald, F. (2007) Anti-Astropolitik—outer space and the orbit of geography. *Progress in human geography*, 31(5): 592-615.

MacDonald, F. (2008) Space and the atom: on the popular geopolitics of Cold War rocketry. *Geopolitics*, 13(4): 611-634.

MacKinnon, D. (2012) Beyond strategic coupling: reassessing the firm-region nexus in global production networks. *Journal of Economic Geography*, 12(1): 227-245.

Mahagaonkar, P. (2009) *Money and ideas: four studies on finance, innovation and the business life cycle*. Volume 25. Springer Science and Business Media.

Mahutga, M. C. (2014) Global models of networked organization, the positional power of nations and economic development. *Review of International Political Economy*, 21(1): 157-194.

Malhotra, (2016) *A Definitive Guide to the Brexit Negotiations*. [online]. Available from: https://hbr.org/2016/08/a-definitive-guide-to-the-brexit-negotiations [Accessed 03 September 2016]

Malmberg, A. and Maskell, P. (2002) The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering. *Environment and Planning A*, 34(3): 429-450.

Maloney, W. A. and McLaughlin, A. (2005) *The European Automobile Industry: Multi Level Governance, Policy and Politics*. London: Routledge.

Manikowski, P. and Weiss, M.A. (2013) The satellite insurance market and underwriting cycles. *The Geneva Risk and Insurance Review*, 38(2): 148-182.

Maral, G. and Bousquet, M. (2011) *Satellite communications systems: systems, techniques and technology*. 5th Edition. Sussex: John Wiley & Sons.

Mariotti, S., Piscitello, L. and Elia, S. (2014) Local externalities and ownership choices in foreign acquisitions by multinational enterprises. *Economic Geography*, 90(2): 187-211.

Markussen, P. and Svendsen, G.T. (2005) Industry lobbying and the political economy of GHG trade in the European Union. *Energy Policy*, 33(2): 245-255.

Marr, B., Schiuma, G. and Neely, A. (2004) The dynamics of value creation: mapping your intellectual performance drivers. *Journal of Intellectual Capital*, 5(2): 312-325.

Marshall, M.N. (1996) Sampling for Qualitative Research. *Family Practice*, 13(6): 522-526.

Marta, L. (2013) National visions of European space governance: Elements for a new institutional architecture. *Space Policy*, 29(1): 20-27.

Mårtensson, M. (2000) A critical review of knowledge management as a management tool. *Journal of Knowledge Management*, 4(3): 204-216.

Martín-de-Castro, G., Delgado-Verde, M., López-Sáez, P. and Navas-López, J.E. (2011) Towards 'an intellectual capital-based view of the firm': origins and nature. *Journal of Business Ethics*, 98(4): 649-662.

Martin, R. (2000) "Institutional approaches in economic geography". In E. Sheppard and Barnes, T. J. (eds.) *A companion to economic geography*. 1st Edition. Oxford: Blackwell Publishers. pp.77-94.

Martin, R., & Sunley, P. (2003) Deconstructing clusters: chaotic concept or policy panacea?. *Journal of Economic Geography*, 3(1): 5-35.

Martin, R. and Sunley, P. (2006) Path dependence and regional economic evolution. *Journal of Economic Geography*, 6(4): 395-437.

Marx, K. and Ryazanskaya, S. (1963) *Theories of Surplus-value (Volume IV of Capital).* Foreign Languages Publishing House.

Mascitelli, R. (2000) From experience: harnessing tacit knowledge to achieve breakthrough innovation. *Journal of Product Innovation Management*, 17: 179–193.

Maskell, P. (2014) Accessing remote knowledge—the roles of trade fairs, pipelines, crowdsourcing and listening posts. *Journal of Economic Geography*, 14(5): 883-902.

Maskell, P., Bathelt, H. and Malmberg, A. (2006) Building global knowledge pipelines: The role of temporary clusters. *European Planning Studies*, 14(8): 997-1013.

Maskell, P. and Malmberg, A. (1999) The competitiveness of firms and regions 'Ubiquitification'and the importance of localized learning. *European Urban and Regional Studies*, 6(1): 9-25.

Maskell, P. and Malmberg, A. (2007) Myopia, knowledge development and cluster evolution. Journal of Economic Geography, 7(5): 603-618.

Mason, C. (2007) *Venture capital: a geographical perspective*. In Landstrom, H. (ed.) *Handbook of Research on Venture Capital.* Cheltenham: Edwar Elgar. pp.86-112.

Mason, C.M. and Harrison, R.T. (2002) Barriers to investment in the informal venture capital sector. *Entrepreneurship & Regional Development*, *14*(3): 271-287.

Massey, D. and Catalano, A. (1978) *Capital and Land: Landownership by Capital in Great Britain*. London: Edward Arnold.

Mattli, W. and Büthe, T. (2005) Global private governance: Lessons from a national model of setting standards in accounting. *Law and Contemporary Problems,* 68(3/4): 225-262.

May, (2011) *Social Research Issues, Methods and Processes*. Maidenhead: McGraw Hill.

Mayer, F. and Gereffi, G. (2010) Regulation and economic globalization: Prospects and limits of private governance. *Business and Politics*, *12*(3): 1-25.

Mayer, F. and Pickles, J. (2010) Re-embedding Governance: Global Apparel Value Chains and Decent Work. In '*Capturing the Gains*', Working Paper No. 01 [online]. Available from: https://globalvaluechains.org/sites/globalvaluechains.org/files/publications/ctg-wp-2010-1.pdf [Accessed 02 November 2015]

Mayntz, R. (2002) "Common goods and governance". In Heritier, A. (ed.) *Common Goods. Reinventing European and International Governance*. Boston: Rowman and Littlefield Publishers. pp.15-27.

Mazurelle, F., Wouters, J. and Thiebaut, W. (2009) Evolution of European Space Governance: Policy, Legal and Institutional Implications. *The Internal Organisation Legal Review,* 6: 155.

Mazzucato, M., 2013. Financing innovation: creative destruction vs. destructive creation. *Industrial and Corporate Change*. 1-17.

McCann, P. and Ortega-Argilés, R. (2015) Smart specialization, regional growth and applications to European Union cohesion policy. *Regional Studies*, 49(8): 1291-1302.

McConnell, V.D. and Schwab, R.M. (1990) The impact of environmental regulation on industry location decisions: The motor vehicle industry. *Land Economics*. 67-81.

McLaughlin, A.M. and Maloney, W.A. (1999) *The European Automobile Industry. Multi-Level Governance.* New York: Routledge.

McLellan, E., MacQueen, K.M. and Neidig, J.L. (2003) Beyond the qualitative interview: Data preparation and transcription. *Field methods*, 15(1): 63-84.

McNeill, D. (2005) Skyscraper geography. *Progress in Human Geography*, 29(1): 41-55.
Mergenthaler, E., and C. H. Stinson. (1992) Psychotherapy transcription standards. *Psychotherapy Research,* 2(2): 125-42.

Metoffice. (2015) *Understanding the role of weather in the supply chain*. [online]. Available from: (http://www.metoffice.gov.uk/media/pdf/g/c/151009_Understanding_the_role_of_weather_in_the_supply_chain_report_Final.pdf [Accessed 22 September 2016]

MOD, (2010) *The UK Military Space Primer*. [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/33691/SpacePrimerFinalWebVersion.pdf. [Accessed 12 December 2015]

Montpert, P. (2013) "Space Insurance". In Lyall, F. (ed.) *Contracting for Space: Contract Practice in the European Space Sector*. Amsterdam: Elsevier. pp.283-181.

Moore, N. and Stokes, P. (2012) Elite interviewing and the role of sector context: an organizational case from the football industry. *Qualitative Market Research: An International Journal,* 15(4): 438-464.

Moser, S. (2008) Personality: a new positionality? *Area*, 40(3): 383-392.

Mosteshar, S. (2010) Regulation of Space Activities in the United Kingdom. In Smith, L.J. *National Regulation of Space Activities*. Amsterdam: Elsevier. pp.357-371.

Mosteshar, S.I. (2013) *A brief survey of space policy and law topics*. [online]. Available from: www.space-institute.org/app/uploads/1364920323_A_brief_Survey_of_Space_Policy_and_Law_Topics_12_3_13.pdf [Accessed 05 June 2016]

Motoyama, Y., Appelbaum, R. and Parker, R. (2011) The National Nanotechnology Initiative: Federal support for science and technology, or hidden industrial policy?. *Technology in Society*, 33(1): 109-118.

Myers, M.D. (2013) *Qualitative Research in Business and Management*. London: Sage Publications.

Mudambi, R. (2008) Location, control and innovation in knowledge-intensive industries. *Journal of Economic Geography*. pp.699-725.

Mudambi, R. and Helper, S. (1998) The 'close but adversarial' model of supplier relations in the US auto industry. *Strategic Management Journal*. 775-792.

Mulhall, R. A. (2012) *Manufacturing change: competitiveness and adjustment through evolving production relationship.* PhD Thesis, University of Birmingham.

Mulhall, R. A. and Bryson, J. R. (2013) The energy hot potato and governance of value chains: power, risk, and organizational adjustment in intermediate manufacturing firms. *Economic Geography*, 89(4): 395-419.

Müller, M. and Stewart, A. (2016) Does temporary geographical proximity predict learning? Knowledge dynamics in the Olympic Games. *Regional Studies*, 50(3): 377-390.

Nachum, L. (1998) Do the diamonds of foreign countries shape the competitiveness of firms? A case study of the Swedish engineering consulting industry. *Scandinavian Journal of Management*, 14(4): 459-478.

Nadvi, K. (2008) Global standards, global governance and the organization of global value chains. *Journal of Economic Geography*, 8(3): 323-343.

NASA, (2014) *NASA's Van Allen Probes Spot an Impenetrable Barrier in Space* [online]. Available from: https://www.nasa.gov/content/goddard/van-allen-probes-spot-impenetrable-barrier-in-space [Accessed 23 April 2016]

NASA, (2016) *What is a satellite?* [online]. Available from: http://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-satellite-58.html [Accessed 23 April 2016]

Neely, A. (2008) Exploring the financial consequences of the servitization of manufacturing. *Operations Management Research*, 1(2): 103-118.

Neely, A., Benedettini, O. and Visnjic, I. (2011) The servitization of manufacturing: Further evidence. In *18th European operations management association conference*, Cambridge. pp. 3-6. (Conference Publications).

Neilson, J., Pritchard, B. and Yeung, H. W. C. (2014) Global value chains and global production networks in the changing international political economy: An introduction. *Review of International Political Economy*, 21(1): 1-8.

North, P. (2015). The business of the Anthropocene? Substantivist and diverse economies perspectives on SME engagement in local low carbon transitions. *Progress in Human Geography*. 1-18.

Nyaga, G.N., Whipple, J.M. and Lynch, D.F. (2010) Examining supply chain relationships: do buyer and supplier perspectives on collaborative relationships differ?. *Journal of Operations Management*, 28(2): 101-114.

O'Cass, A. and Sok, P. (2013) The role of intellectual resources, product innovation capability, reputational resources and marketing capability combinations in SME growth. *International Small Business Journal*, 0(0):1-23.

O'Regan, N. and Sims, M. A. (2008) Identifying high technology small firms: a sectoral analysis, *Technovation*, 28(7): 408-423.

OECD, (2012) *OECD Handbook on measuring the space economy*. [online]. Available from: http://www.oecdbookshop.org/get-it.php?REF=5KG0NVKZ6TKD&TYPE=browse [Accessed 15 December 2015]

Dictionary, O.E. (2015) *Oxford English Dictionary*. Oxford: Oxford University Press [online]. Available from: http://www.oed.com [Accessed 14 May 2016]

Ofcom, (2016) *About Ofcom* [online]. Available from: http://www.ofcom.org.uk/about/ [Accessed 08 February 2016]

Oh, J. and Rhee, S.K. (2008) The influence of supplier capabilities and technology uncertainty on manufacturer-supplier collaboration: a study of the Korean automotive industry. *International Journal of Operations & Production Management*, 28(6): 490-517.

Oinas, P. (1999) Voices and silences: the problem of access to embeddedness. *Geoforum*, 30(4): 351-361.

Olavarrieta, S. and Friedmann, R. (2008) Market orientation, knowledge-related resources and firm performance. *Journal of Business Research*, 61(6): 623-630.

Oltmann, S.M. (2015) Data, censorship, and politics: Analyzing the restricted flow of information in federal scientific policy development. *Journal of the Association for Information Science and Technology*, 66(1): 144-161.

Onwuegbuzie, A.J., Leech, N.L. and Collins, K.M. (2012) Qualitative analysis techniques for the review of the literature. *The Qualitative Report*, 17(28): 1-15.

Ostrom, V., Tiebout, C. and Warren, R. (1961) The organization of government in metropolitan areas. *American Political Science Review*, 55: 831-842

Palmer, M. and Quinn, B (2003) The strategic role of investment banks in the retailer internationalisation process: Is this venture marketing?. *European Journal of Marketing*, 37(10): 1391-1408.

Palmer, W. (2013) Public–private partnerships in the administration and control of Indonesian temporary migrant labour in Hong Kong. *Political Geography*, 34: 1-9.

Papacharissi, Z. (2009) The virtual geographies of social networks: a comparative analysis of Facebook, LinkedIn and a Small World. *New Media and Society*, 11(1-2): 199-220.

Parida, V., Westerberg, M. and Frishammar, J. (2012) Inbound open innovation activities in high-tech SMEs: the impact on innovation performance. *Journal of Small Business Management*, 50(2): 283-309.

Pattberg, P. (2005) The institutionalization of private governance: How business and nonprofit organizations agree on transnational rules. *Governance*, 18(4): 589-610.

Patton, M. Q. (2002) *Qualitative Research and Evaluation Methods*. 3rd Edition. Thousand Oaks, CA: Sage.

Pavitt, K. (2002) Innovating routines in the business firm: what corporate tasks should they be accomplishing? *Industrial and Corporate Change*, 11(1): 117-133.

Pavlínek, P. (2012) The internationalization of corporate R&D and the automotive industry R&D of East-Central Europe. *Economic Geography*, 88(3): 279-310.

Peck, J. and Theodore, N. (2007) Variegated capitalism. *Progress in Human Geography*, 31(6): 731-772.

Peteraf, M. A. (1993) The cornerstones of competitive advantage: A resource-based view, *Strategic Management Journal*, 14(3): 179-191.

Petrick, J. A., Scherer, R. F., Brodzinski, J. D., Quinn, J. F. and Ainina, M. F. (1999) Global leadership skills and reputational capital: Intangible resources for sustainable competitive advantage, *The Academy of Management Executive*, 13(1): 58-69.

Perez, C. (2009) Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*. 1-18.

Phelps, N.A. and Fuller, C. (2016) Inertia and change in multinational enterprise subsidiary capabilities: an evolutionary economic geography framework. *Journal of Economic Geography*, 16(1): 109-130.

Pike, A. and Pollard, J. (2010) Economic geographies of financialization. *Economic Geography*, 86(1): 29-51.

Plumb, K. (2005) Continuous processing in the pharmaceutical industry: changing the mind set. *Chemical Engineering Research and Design*, 83(6): 730-738.

Podolny, J.M. (1993) A status-based model of market competition. *American Journal of Sociology*. 829-872.

Pollard, J.S. (2003) Small firm finance and economic geography. *Journal of Economic Geography*, 3(4): 429-452.

Ponds, R., Van Oort, F. and Frenken, K. (2010) Innovation, spillovers and university–industry collaboration: an extended knowledge production function approach. *Journal of Economic Geography*, 10(2): 231-255.

Ponte, S., & Gibbon, P. (2005) Quality standards, conventions and the governance of global value chains. *Economy and Society*, 34(1): 1-31.

Ponte, S. and Sturgeon, T. (2014) Explaining governance in global value chains: A modular theory-building effort. *Review of International Political Economy*, 21(1): 195-223.

Porter, M. E. (1990). The competitive advantage of nations. *Harvard Business Review*, 68(2): 73-93.

Porter M, E. (1992) Competitive Advantage: Creating and Sustaining Superior Performance. Issue 10. London: PA Consulting Group.

Porter, M. E. (2000) Location, competition, and economic development: Local clusters in a global economy. *Economic development quarterly*, 14(1): 15-34.

Potts, S. (2016) Reterritorializing economic governance: Contracts, space, and law in transborder economic geographies. *Environment and Planning A*, 48(3): 523-539.

Priem, R. L. and Butler, J. E. (2001) Is the resource-based "view" a useful perspective for strategic management research?. *Academy of Management Review,* 26:22–40.

Priest, T. (2007) Extraction not creation: The history of offshore petroleum in the Gulf of Mexico. *Enterprise and Society*, 8(02): 227-267.

Prince, R. (2012) Policy transfer, consultants and the geographies of governance. *Progress in Human Geography*, 36(2): 188-203.

Raco, M. (1999) Competition, collaboration and the new industrial districts: Examining the institutional turn in local economic development. *Urban studies*, 36(5/6): 951-967.

RAL Space (2016) *About RAL Space* [online]. Available from: http://www.ralspace.stfc.ac.uk/RALSpace/ [Accessed 01 October 2015]

Rafiqui, P. S. (2009) Evolving economic landscapes: why new institutional economics matters for economic geography. *Journal of Economic Geography*, 9(3): 329-353.

Rainnie, A., Herod, A. and McGrath-Champ, S. (2011) Review and positions: Global production networks and labour. *Competition and Change*, 15(2): 155-169.

Ramey, V.A (2011) Can government purchases stimulate the economy? *Journal of Economic Literature*, 49(3): 673-685.

Rantisi, N. M. (2014) Exploring the role of industry intermediaries in the construction of 'Local Pipelines': The case of the Montreal Fur Garment Cluster and the rise of Fur–Fashion connections. *Journal of Economic Geography*, 14(5): 955-971.

Rapaccini, M. (2015) Pricing strategies of service offerings in manufacturing companies: a literature review and empirical investigation. *Production Planning and Control*, 26(14-15): 1247-1263.

Redding, S. J. (2010) The Empirics of New Economic Geography. *Journal of Regional Science*, 50(1): 297-311.

Reed, M. G. and Bruyneel, S. (2010) Rescaling environmental governance, rethinking the state: A three-dimensional review. *Progress in Human Geography*. 1-8.

Reeves, M. and Deimler, M. (2011) Adaptability: The new competitive advantage. *Harvard Business Review*. 135-41.

Richardson, J. (1993) Parallel sourcing and supplier performance in the Japanese automobile industry. *Strategic Management Journal*, 14(5): 339-350.

Richardson, J. (2012) New Governance or Old Governance? A Policy Style Perspective. In Levi-Faur, D. (ed.). *The Oxford handbook of governance*. Oxford: Oxford University Press.

Riebeek, H. (2009) *Catalogue or Earth Satellite Orbits*. NASA [online]. Available from: http://earthobservatory.nasa.gov/Features/OrbitsCatalog/ [Accessed 19 May 2016]

Ritchie, J. and Lewis, J. (eds.) (2013) *Qualitative Research Practice. A Guide for Social Science Students*. London: Sage Publications.

Robson, C. (2002) *Real World Research: A Resource for Social Scientists and Practioner-Researchers*. 2nd Edition. Oxford: Blackwell Publishers.

Rochette, J., Unger, S., Herr, D., Johnson, D., Nakamura, T., Packeiser, T., Proelss, A., Visbeck, M., Wright, A. and Cebrian, D. (2014) The regional approach to the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction. *Marine Policy*, 49: 109-117.

Roe, M. (2009) Multi-level and polycentric governance: effective policymaking for shipping. *Maritime Policy and Management*, 36(1): 39-56.

Rodrik, D. (2004). *Industrial policy for the twenty-first century*. [online]. Available from: http://papers.ssrn.com/soL3/papers.cfm?abstract_id=666808 [Accessed 06 June 2016]

Roper, S. and Hewitt-Dundas, N. (2012) Catalysing open innovation through publicly-funded R&D: A comparison of university and company-based research centres. *International Small Business Journal*, 0(0): 1-21.

Rosell, D. T., Lakemond, N. and Wasti, S. N. (2014) Integrating knowledge with suppliers at the R&D-manufacturing interface. *Journal of Manufacturing Technology Management*, 25(2): 240-257.

Rose, G. (1997) Situating knowledges: positionality, reflexivities and other tactics, *Progress in Human Geography*, 21(3): 305-320.

Rosenau J. N. (1995) Governance in the twenty-first century. *Global Governance*, 1:13–43.

Rossetti, C. and Choi, T.Y. (2005) On the dark side of strategic sourcing: experiences from the aerospace industry. *The Academy of Management Executive*, 19(1): 46-60.

Rothsetin, B. (2012) "Good Governance". In Levi-Faur, D. (ed.) T*he Oxford Handbook of Governance*. Oxford: Oxford University Press. pp.1431-155.

Rugman, A. M. and Verbeke, A. (1993) How to operationalize Porter's diamond of international competitiveness. *The International Executive*, 35(4): 283-299.

Rusanen, H., Halinen, A. and Jaakkola, E. (2014) Accessing resources for service innovation–the critical role of network relationships. *Journal of Service Management*, 25(1): 2-29.

Rutherford, T. and Holmes, J. (2008) 'The flea on the tail of the dog': power in global production networks and the restructuring of Canadian automotive clusters, *Journal of Economic Geography*, 8: 519-544.

Rychen, F. and Zimmermann, J.B. (2008) Clusters in the global knowledge-based economy: knowledge gatekeepers and temporary proximity. *Regional Studies*, 42(6): 767-776.

SA, (2016) *Precision Farming* [online]. Available from: https://sa.catapult.org.uk/ideasopportunities/competitions/european-satellite-navigation-competition/esnc-success-stories/intelligent-precision-farming/ [Accessed 02 April 2016]

SA, (2016) *About us* [online]. Available from: https://sa.catapult.org.uk/about-us/who-we-are/ [Accessed 02 April 2016]

Saccani, N., Visintin, F. and Rapaccini, M. (2014) Investigating the linkages between service types and supplier relationships in servitized environments. *International Journal of Production Economics*, 149: 226-238.

Sachs, J. D. (2005) *The End of Poverty: Economic Possibilities For Our Time*. New York: Penguin.

Sadeh, E. (2002). *Space politics and policy: an evolutionary perspective.* Volume 2. Springer Science & Business Media.

Salamon, L. M. and Siegfried, J. J. (1977) Economic power and political influence: The impact of industry structure on public policy. *American Political Science Review*, 71(03): 1026-1043.

Sassen, S. (2001) *The Global City: New York, London, Tokyo*. Princeton: Princeton University Press.

Satellitemarkets, (2011) *Brazil: Latin America's Leading Satellite Market* [online]. Available from: http://www.satellitemarkets.com/news-analysis/brazil-latin-americas-leading-satellite-market [Accessed 03 March 2016]

Sayer, R.A. (1995) Radical Political Economy: Critique and Reformulation. Blackwell Publishing.

Sayer, A. (2001) For a critical cultural political economy. *Antipode*, 33(4): 687-708.

Schacht, W. H. (2010) *Industrial competitiveness and technological advancement: Debate over government policy*. Collingdale, PA: Diane Publishing.

Tanaka, Y. (2004) Zonal and integrated management approaches to ocean governance: reflections on a dual approach in international law of the sea. *The International Journal of Marine and Coastal Law*, 19(4): 483-514.

Tewari, M. (2006) Adjustment in India's textile and apparel industry: reworking historical legacies in a post-MFA world. *Environment and Planning A*, 38(12): 2325-2344.

Scott, A. J. (1980) *The urban land nexus and the state*. London: Pion Limited.

Scott, C. (2002) Private regulation of the public sector: a neglected facet of contemporary governance. *Journal of Law and Society*, 29(1): 56-76.

Scott F (2010) Foreword: 'Making data speak'. In Wilkins, G. (ed.) *Distributed Urbanism: Cities After Google Earth*. Abingdon: Routledge.

Scott, H.V. (2008) Colonialism, landscape and the subterranean. *Geography Compass*, 2(6): 1853-1869.

Scott, P. (1996) The Global Positioning System: Policy Issues for an Information Technology. *Space Policy*, 12(4): 265-275.

Schmutzler, A. (1999) The New Economic Geography. *Journal of Economic Surveys*, 13(4): 355-379.

Schumpeter, J.A. (1939) *Business cycles*. Volume 1. New York: McGraw-Hill.

Teodora, S. and Bruston, J. (2009) Current Barriers and Factors of Success in the Diffusion of Satellite Services in Europe. *Space Policy,* 25(4): 209-217.

Selnes, F., & Sallis, J. (2003) Promoting relationship learning. *Journal of Marketing*, 67(3), 80-95.

Seyoum, B. (2007) Revealed comparative advantage and competitiveness in services: A study with special emphasis on developing countries. *Journal of Economic Studies*, 34(5): 376-388.

Skelcher, C. (2005) Jurisdictional integrity, polycentrism, and the design of democratic governance. *Governance*, 18(1): 89-110.

Shackelford, S. J. (2009) Tragedy of the Common Heritage of Mankind. *The*. *Stan. Envtl. LJ*, 28: 109-121.

Shafaei, R., Shahriari, H. and Moradi, M. (2009) Investigation of leather industry competitiveness in Iran. *Journal of Fashion Marketing and Management: An International Journal*, 13(3): 343-357.

Shaw, E. (1999) A guide to the qualitative research process: evidence from a small firm study. *Qualitative Market Research: An International Journal*, 2(2): 59-70.

Sheldon, J. B. (2014) Geopolitics and Cyber Power: Why Geography Still Matters. *American Foreign Policy Interests*, 36(5): 286-293.

Sheppard, E. (2011) Geography, nature, and the question of development. *Dialogues in human geography*, *1*(1): 46-75.

Schmidt-Tedd, B. (2011) The Geographical Return Principle and its Future Within The European Space Policy. In Smith, L.J. and Baumann, I. (eds.) *Contracting for space: contract practice in the European space sector*. Surrey: Ashgate Publishing.

Schoenberger, E. (1991) The corporate interview as a research method in economic geography. *The Professional Geographer*, 43(2): 180-189.

Shonfield, A. (1965) *Modern Capitalism; the changing balance of public and private power*. Oxford: Oxford University Press.

Siddiqi, A.A. (2000) *Challenge to Apollo: the Soviet Union and the space race, 1945-1974*. NASA [online]. Available from: http://ntrs.nasa.gov/search.jsp?R=20000088626 [Accessed 3 June 2016]

Simmie, J. and Martin, R. (2010) The economic resilience of regions: towards an evolutionary approach. *Cambridge Journal of Regions, Economy and Society*, 3(1): 27-43.

Singh, R. K., Garg, S. K. and Deshmukh, S. G. (2008) Strategy development by SMEs for competitiveness: a review. *Benchmarking: An International Journal*, 15(5): 525-547

Slepniov, D., Wæhrens, B. V., & Johansen, J. (2014) Dynamic roles and locations of manufacturing: imperatives of alignment and coordination with innovation. *Journal of Manufacturing Technology Management*, 25(2): 198-217.

Sloterdijk, P. (1998). Sphären: Blasen, Mikrosphärologie. Frankfurt am Main: Suhrkamp.

Smith, A. (1776). The Wealth of Nations. *New York: The Modern Library*.

Smith, A. (2015) The state, institutional frameworks and the dynamics of capital in global production networks. *Progress in Human Geography*, 39(3): 290-315.

Smith, A., Pickles, J., Buček, M., Pástor, R. and Begg, B. (2014) The political economy of global production networks: regional industrial change and differential upgrading in the East European clothing industry. *Journal of Economic Geography*, 14(6): 1023-1051.

Smith, A., Rainnie, A., Dunford, M., Hardy, J., Hudson, R. and Sadler, D. (2002) Networks of value, commodities and regions: reworking divisions of labour in macro-regional economies. *Progress in Human Geography*, 26(1): 41-63.

Smith, L.J. (2011) The Principles of International Space Law and their Relevance to Space Industry Contracts. In Smith, L.J. and Baumann, I. (eds.) *Contracting for space: contract practice in the European space sector*. Surrey: Ashgate Publishing.

Smith, L.J. and Baumann, I. (2011) (eds.) *Contracting for space: contract practice in the European space sector*. Surrey: Ashgate Publishing.

Sokol, M. (2013) Towards a 'newer' economic geography? Injecting finance and financialisation into economic geographies. *Cambridge Journal of Regions, Economy and Society*, 6(3): 501-515.

Spacenews (2016) *Britain's quitting the EU, but will it be forced out of EU space programs*? [online] Available from: ://spacenews.com/britains-quitting-the-eu-but-will-it-be-forced-out-of-eu-space-programs/ [Accessed 01 February 2016]

Spence, M. (1974) *Market signalling.* Harvard University Press.

Spencer, L., Ritchie, J. and O'Connor, W. (2003) Analysis: practices, principles and processes. In Ritchie, J. and Lewis, J. (eds.) *Qualitative Research Practice. A Guide for Social Science Students*. London: Sage Publications. pp.199-218.

Spinardi, G. (2006) Science, Technology, and the Cold War: The Military Uses of the Jodrell Bank Radio Telescope. *Cold War History*, 6(3): 279-300.

Starr, R., Newfrock, J. and Delurey, M. (2003) Enterprise resilience: managing risk in the networked economy, *Strategy and Business*. 70-79.

Stern, P, C. (1979) *Evaluating Social Science Research*. Oxford: Oxford University Press.

Stone, D. (2013) *Knowledge actors and transnational governance: The private-public policy nexus in the global agora*. Basingstoke: Palgrave Macmillan.

Storper, M. (2014) Governing the large metropolis. *Territory, Politics, Governance*, *2*(2): 115-134.

Stuart, J. (2009) "Unbundling sovereignty, territory and the state in outer space: two approaches". In Bormann, N. and Sheehan, M. (eds.) (2009) *Securing Outer Space: International Relations Theory and the Politics of Space*. Oxon: Routledge. pp.8-23.

Sturgeon, T. J. (2001) How Do We Define Value Chains and Production Networks?. *IDS bulletin*, 32(3): 9-18.

Sturgeon, T., and Lee, J. (2001) *Industry co-evolution and the rise of a shared supply-base for electronics manufacturing*. Working paper 01-003. Cambridge: Mass Industrial Performance Center.

Sturgeon, T., Van Biesebroeck, J. and Gereffi, G. (2008) Value chains, networks and clusters: reframing the global automotive industry. *Journal of Economic Geography*, 8(3): 297-321.

Sturges, J.E. and Hanrahan, K.J. (2004) Comparing telephone and face-to-face qualitative interviewing: a research note. *Qualitative research*, 4(1): 107-118.

Summerer, L. (2011) Signs of Potentially Disruptive Innovation in the Space Sector, *International Journal of Innovation Science*, 3(3): 127-140.

Sunley, P. (2008) Relational economic geography: a partial understanding or a new paradigm?. *Economic Geography*, 84(1): 1-26.

Surroca, J., Tribó, J.A. and Waddock, S. (2010) Corporate responsibility and financial performance: The role of intangible resources. *Strategic Management Journal*, 31(5): 463-490.

Sveiby, K.E., 2001. A knowledge-based theory of the firm to guide in strategy formulation. *Journal of Intellectual Capital*, *2*(4): 344-358.

Sydow, J., Schreyögg, G. and Koch, J. (2009) Organizational path dependence: Opening the black box. *Academy of Management Review*, 34(4): 689-709.

Symonds, J. (ed.) (2009) *Ubiquitous and Pervasive Computing: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*. IGI Global.

Tangpong, C., Michalisin, M.D. and Melcher, A.J. (2008) Toward a typology of buyer–supplier relationships: A study of the computer industry. *Decision Sciences*, 39(3): 571-593.

Taylor, M. and Asheim, B. (2001) The concept of the firm in economic geography. *Economic Geography*, 77(4): 315-328.

Teece, D.J. (2010) Business models, business strategy and innovation. *Long Range Planning*, 43(2): 172-194.

Thompson, G. (1977) The relationship between the financial and industrial sector in the UK economy. *Economy and Society*, 6(3): 235-283.

Thompson, J. C. (1996). Space for Rent: The International Telecommunications Union, Space Law, and Orbit/Spectrum Leasing. *J. Air L. & Com*. 62: 279-289.

Thrift, N.J. (1994) "On the social and cultural determinants of international financial centres: the case of the City of London". In Corbridge, S., Martin, R. and Thrift, N. (eds.) *Money, Power, and Space.* Oxford: Blackwell. pp.327-355.

Thune, T. (2007) University-industry collaboration: the network embeddedness approach. *Science and Public Policy*, 34(3): 158-168.

Todd, D. (1992). “Internationalisation of the aircraft industry: substance and myth”. In Van Liemt. G. (ed.) *Industry on the move*. 1st Edition. Geneva: International labour office. pp.117-141.

Tokatli, N. (2007) Asymmetrical power relations and upgrading among suppliers of global clothing brands: Hugo Boss in Turkey. *Journal of Economic Geography*, 7(1): 67-92.

Tokatli, N. (2012) Old firms, new tricks and the quest for profits: Burberry’s journey from success to failure and back to success again. *Journal of Economic Geography*, 12(1): 55-77.

Tokatli, N. (2013) Toward a better understanding of the apparel industry: a critique of the upgrading literature, *Journal of Economic Geography*, 13: 993-1011.

Tonts, M., Plummer, P. and Taylor, M. (2012) Power, enterprise and employment growth in Australian small-and medium-sized manufacturing firms. *Journal of Economic Geography*. 1-28.

Tóth, G., Sokolov, I.V., Gombosi, T.I., Chesney, D.R., Clauer, C.R., De Zeeuw, D.L., Hansen, K.C., Kane, K.J., Manchester, W.B., Oehmke, R.C. and Powell, K.G. (2005) Space Weather Modeling Framework: A new tool for the space science community. *Journal of Geophysical Research: Space Physics*, 110(12): 1-21.

TravelAI (2016) *Travel AI Info* [online]. Available from: http://www.travelai.info/ [Accessed 4 July 2016]

Trapp, T. J. (2013) Taking up space by any other means: coming to terms with the non-appropriation article of the outer space treaty. *University of Illinois Law Review*, 4:1681-1713.

Tremblay, V. J. and Tremblay, C. H. (2007). *Industry and firm studies*. Oxon: ME Sharpe.

Turban, D. B., Forret, M. L. and Hendrickson, C. L. (1998) Applicant attraction to firms: Influences of organization , job and organizational attributes, and recruiter behaviours, Journal of Vocational Behavior, 52(1), pp.24-44.

Turco, A.L. and Maggioni, D. (2015) On firms’ product space evolution: the role of firm and local product relatedness. *Journal of Economic Geography*. 1-32.

Turner, D. W. (2010) Qualitative interview design: A practical guide for novice investigators, *The Qualitative Report*, 15(3): 754-760.

UKESNC (2015) *UK Space Agency* [online]. Available from: http://ukesnc.com/uk-space-agency/ [Accessed 09 August 2015]

UK Space Agency, (2014*) Innovation Growth Strategy*. [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298362/igs-action-plan.pdf [Accessed 15 December 2015]

UK Space Agency. (2015) *UK Space Agency Corporate Plan 2015-2016*. [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/448656/Final_Corporate_Plan_format_2015-16_pages.pdf [Accessed 22 February 2016]

UKspace. (2014) *Government Response to Space Growth Action Plan*. [online]. Available from: (http://www.ukspace.org/wp-content/uploads/2014/05/Government-Response-Space-Growth-Action-Plan.pdf [Accessed 23 June 2016]

Ulaga, W. and Eggert, A. (2006) Relationship value and relationship quality: Broadening the nomological network of business-to-business relationships. *European Journal of marketing*, 40(3/4): 311-327.

UNISDR, (2015) *Critical Infrastructure Protection and Resilience Europe 2015*. [online]. Available from: http://www.unisdr.org/we/inform/events/37263 [Accessed 02 May 2016]

UNOOSA, (2016) *Introduction to Outer Space Treaty* [online]. Available from: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html [Accessed 02 May 2016]

Urde, M., Greyser, S. A. and Balmer, J. M. (2007) Corporate brands with a heritage. *Journal of Brand Management*, 15(1): 4-19.

Valentine, G. (2005) Tell me about… Using interviews as a research methodology. In Flowerdew, R. and Martin, D. (eds.) *Methods in Human Geography: Issues and Debates, A guide for students doing a research project*. 2nd Edition. Essex: Pearson Education. pp.110-127.

Valentine, G. (2005b) Geography and ethics: moral geographies? Ethical commitment in research and teaching. *Progress in Human Geography*, 29(4): 483-487.

Van der Vooren, A. Alkemade, F. and Hekkert, M.P. (2012) Effective public resource allocation to escape lock-in: The case of infrastructure-dependent vehicle technologies. *Environmental Innovation and Societal Transitions*, 2: 98-117.

Vanchan, V. and Bryson, J.R. (2015) "Design and manufacturing: the competitiveness of American, European and Chinese industrial design companies". In Bryson, J.R., Clark, J. and Vanchan, V. (eds.) *Handbook of Manufacturing Industries in the World Economy*. Cheltenham: Edward Elgar. pp.147-163.

Van Teijlingen, E. and Hundley, V. (2001) The importance of pilot studies. *Social research update*. 35: 1-4.

Vargo, S. L., Maglio, P. P. and Akaka, M. A. (2008) On value and value co-creation: A service systems and service logic perspective. *European management journal*, 26(3): 145-152.

Varshney, U., Vetter, R.J. and Kalakota, R. (2000) Mobile Commerce: a New Frontier. *Computer*, 33(10): 32-38.

Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I. and Manjarrés-Henríquez, L. (2008) The effect of external and internal factors on firms' product innovation. *Research Policy*, 37(4): 616-632.

Venet, C. (2012) European space governance: The outlook. *Space Policy*, 28(1): 59-60.

Vesalainen, J. and Kohtamäki, M. (2015) Toward a typological view of buyer–supplier relationships: Challenging the unidimensional relationship continuum. *Industrial Marketing Management*, 49: 105-115.

Voulgaris, F. and Lemonakis, C. (2014) Creating a Business Competitiveness Index: An Application to Greek Manufacturing Firms. *Journal of Transnational Management*, 19(3): 191-210.

Wallsten, S.J. (2000) The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. *The RAND Journal of Economics*. 82-100.

Walker, R.A. (2000) The Geography of Production. In Sheppard, E. and Barnes, T.J. (eds.) (2000) *A Companion to Economic Geography*. Oxford: Blackwell. pp.113–132.

Walsh, G. and Beatty, S. E. (2007) Customer-based corporate reputation of a service firm: scale development and validation, *Journal of the Academy of Marketing Science*, 35(1): 127-143.

Wan, W., Hoskisson, R., Short, J. and Yiu, D. (2011) Resource-based theory and corporate diversification: Accomplishments and opportunities. *Journal of Management*, 37: 1335-1368.

Wang, S. C. (2009) The Making of New 'Space': Cases of Transatlantic Astropolitics. *Geopolitics*, 14(3): 433-461.

Warf, B. (2006) International Competition Between Satellite and Fiber Optic Carriers: A Geographic Perspective. *The Professional Geographer*, 58(1): 1-11.

Warf, B. (2007) 'Geopolitics of the satellite industry'. *Tijdschrift voor Economische en Sociale Geografie*, 98(3): 385–97.

Webster, E. (2004) Firms' decisions to innovate and innovation routines. *Economics of Innovation and New Technology*, 13(8): 733-745.

Weick, K.E. (2001) *Making Sense of the Organization*. Oxford: Blackwell Business.

Weizman, E. (2002) *Introduction to the politics of verticality*. [online]. Available from: https://www.opendemocracy.net/ecology-politicsverticality/article_801.jsp [Accessed 09 September 2015]

Welsh, E. (2002) *Dealing with data: Using NVivo in the qualitative data analysis process* [online]. Available from: http://www.qualitative-research.net/index.php/fqs/article/viewArticle/865 [Accessed 02 June 2016]

Weston, C., Gandell, T., Beauchamp, J., McAlpine, L., Wiseman, C. and Beauchamp, C. (2001) Analyzing interview data: The development and evolution of a coding system. *Qualitative sociology*, 24(3): 381-400.

Wilhelmsson, M. (2008) House price depreciation rates and level of maintenance. *Journal of Housing Economics*, 17(1): 88-101.

Wilks, S. and Wright, M. (eds.) (1987) *Comparative Government-Industry Relations: Western Europe, the United States, and Japan*. Oxford: Clarendon Press.

Witzig, L., Spencer, J. and Galvin, M. (2012) Organizations' use of LinkedIn: An analysis of nonprofits, large corporations and small businesses. *Marketing Management Journal*, 22(1): 113-121.

Wójcik, D. (2006) Convergence in corporate governance: evidence from Europe and the challenge for economic geography. *Journal of Economic Geography*, 6(5): 639-660.

Wójcik, D. (2009) Geography of stock markets. *Geography Compass*, 3(4): 1499-1514.

Wójcik, D. (2011) Finance at the crossroads: geographies of the financial crisis and its implications. *Environment and Planning A*, 43(8): 1756-1760.

Wouters, J. and Hansen, R. (2013) *The Other Triangle in European Space Governance: The European Union, the European Space Agency and the United Nations*. [online]. Available from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2371313 [Accessed 04 June 2016]

Wray, F. (2011) Rethinking the venture capital industry: relational geographies and impacts of venture capitalists in two UK regions. *Journal of Economic Geography*. 1-23.

Wu, Z. and Choi, T.Y. (2005) Supplier–supplier relationships in the buyer–supplier triad: building theories from eight case studies. *Journal of Operations Management*, 24(1): 27-52.

Wuyts, S. and Geyskens, I. (2005) The formation of buyer—supplier relationships: detailed contract drafting and close partner selection. *Journal of Marketing*, 69(4): 103-117.

Yang, D.Y.R. and Coe, N.M. (2009) The governance of global production networks and regional development: A case study of Taiwanese PC production networks. *Growth and Change*, 40(1): 30-53.

Zaefarian, G., Henneberg, S.C. and Naudé, P. (2011) Resource acquisition strategies in business relationships. *Industrial Marketing Management*, 40(6): 862-874.

Zielonka, J. (2007) Plurilateral governance in the enlarged European Union. *JCMS: Journal of Common Market Studies*, 45(1): 187-209.

Zubarevich, N. (2009) Regional Development and Regional Policy in Russia During Ten Years of Economic Growth. *Journal of the New Economic Association*, (1-2): 161-174.

Zurn, M. (2012) "Global Governance as Multi Governance". In Levi-Faur, D. (ed.) *The Oxford Handbook of Governance*. Oxford: Oxford University Press. pp.1431-155.