Defining the defence industry using an ecological system and the application of ecological taxonomy

Richard Fisher
Research Fellow in Global Defence Acquisition
Centre for Defence Acquisition
Cranfield Defence & Security
Cranfield University
Defence Academy of the United Kingdom
Shrivenham
SN6 8LA

Abstract

This research examines the creation of the ecosystem where the defence industry is described using an ecological taxonomy and the development of the theory supporting classification of defence organisations within that taxonomy.

Using recognised terminology, comparisons are made between defence organisations and organisms, associations and partnerships with populations and species, leading up to industry sectors and ecosystems and multiple sectors and biomes.

The value of this approach is the ability to identify susceptibilities, resilience issues and the scope and interdependencies of defence. It enables those involved to reflect upon the organic natures of a complex system of systems.

This work has already been applied to improving the visibility and transparency of the issues facing UK-based small-to-medium enterprises and the approach to exporting defence products.

Introduction

The concept of organisations and businesses operating outside of the regulated structures within which they're designed, and being susceptible to the influences of the social aspects of their staff and the networks that develop within them, has been

considered for many years (Barnard 1963). The activities of the staff outside of work cannot be separated from those inside and the networks and relationships that they may establish socially, or through other organised activities may well create an informal management structure that operates both inside and outside of business activities. Barnard (1963) identifies this as a form of industrial ecology that has great complexity and requires detailed insight to be able to be a student of management. The term 'industrial ecology' continues to be used to describe the complexity of organisations and their interactions with each other. Tsuchiya et al. (1986) identifies some of the ecological termination that can be applied to industrial ecology and their usefulness:

> "The structure and inner-working of an industrial society resemble those of a natural ecosystem. The concepts in ecology such as habitat, succession, trophic level, limiting factors and community metabolism can also apply to the study of the ecology of an industrial society." (Tsuchiya et al. 1986, p.330)

In English language literature however, the focus on the use of the 'industrial ecology' is as a descriptor for environmental sustainability (Frosch & Gallopoulos 1989). It is not dissimilar to the concept of the circular economy, promoting the creation of self-sustaining resource and material supplies by concentrating on minimising waste production and maximising opportunities from any waste that is produced (Frosch 1992; Ausubel 1992). Frosch (1992) does identify a greater granularity using the ecological analogies: Industrial processes are identified as organisms and must be considered to relate to and interact with the other organisms (processes) within the network (ecosystem). Whole economies are considered by Nordhaus (1992) to act as ecological systems because "everything is connected to everything else." Multiple definitions of industrial ecology are given by Garner and Keoleian (1995) and they usefully identify the different terms across different hierarchies based on case studies (Keoleian et al. 1995). These are shown in Table 1; however, the purpose of the research relates to life cycle analyses and maintains that the main aim of research in this area relates to sustainable development.

Table 1 - Organizational Hierarchies (Keoleian et al. 1995)

Political	Social Organizations	Industrial Organizations	Industrial Systems	Ecological Systems

United Nations Environmental Programme	World human population	International Organization for Standardization	Global human material & energy flows	Ecosphere
United States (Environmental Protection Agency, Department of Energy)	Cultures	Trade associations	Sectors (e.g. transportation & health care)	Biosphere
State of Michigan (Michigan Department of Natural Resources)	Communities	Corporation / companies	Corporations & institutions	Biogeographical region
Washtenaw County	Households	Divisions	Produce systems	Biome landscape
City of Ann Arbor	Individuals / consumers	Product development teams	Life cycle stages	Ecosystem
Individual Voter		Individuals	Unit steps	Organism

Notwithstanding this dominant environmental approach, there is a body of research that discusses business-related ecosystems. Garner and Keoleian (1995) do identify that the approach of ecosystem analysis is a systems view, pointing towards systems engineering as a potential source for further information. Examining this area identifies that 'Systems of Systems' can be representative of the ecological complexity that exist within industry yet provide limited usefulness in developing translatable analogies. The comparison of business behaviour to competition within natural ecosystems by Moore (1993) provides an analogy with business evolution and identifies that "from an ecological perspective, it matters not which particular ecosystems stay alive; it's only essential that competition among them remains fierce and fair." Shaw and Allen (2015) provide descriptors to support their interpretation of the ecological terms identified in organisation mapping. These include some of those in Table 1 and additional terms not discussed elsewhere. The focus of this research was the healthcare system in the United Kingdom and identifies a limitation that it may not be applicable to other sectors, but further research would be appropriate.

An ecosystem approach to innovation has been considered to improve the interactions and communications between organisations across supply networks and research areas, as well as the process of innovation compared to natural evolution (Rabelo & Bernus 2015). This has provided some structure to the business models based upon ecosystems and enables organisations to identify a suitable innovation strategy dependent upon their placement with the ecosystem (Paulus-Rohmer et al. 2016), justifying the need for ecosystem mapping of businesses and industries.

The social context of industrial ecosystems has also been investigated and analysed (Schiller et al. 2014); notwithstanding the focus on materials that this research has, it does recognise that there are tiered structures and networks that operate outside of material flows yet still influence them. The “non-physical, non-business, information, and invisible relationships” (Tsujimoto et al. 2017) are identified as the strategic value of an ecosystem approach.

Iansiti and Levien (2004) discuss the dominance of ‘keystone species’ within business ecosystems, citing Wal-Mart and Microsoft as examples and drawing out the analogies with natural ecosystems further, identifying additional appropriate terminology in their assessment of the usefulness of the analogy. They conclude that it isn’t a perfect analogy and that the common use of the term ‘ecosystem’ is more aligned to that of the biological term ‘community’ and this is part of the challenge faced in applying the terminology to specific industries. Roles such as keystone species are identified, alongside value dominators and niches as part of an analysis framework (Nuseibah & Wolff 2015) which focusses on the assessment of the health and the sustainability of an established business ecosystem; however, it fails to identify how to map an ecosystem in the first instance.

Within defence, the term ‘ecosystem’ has been used to describe the interconnected nature of an industry with blurred boundaries (Heidenkamp et al. 2011; Newall 2014). It’s been highlighted as a model to use for establishing strategic direction in early phases of an emergent industry (Anon 2017) and for recognising the need to use alternative methods of performance management where organisations may not be within the regular sphere of an industry (Maggiani 2017). Whilst these are useful approaches to set the scene of a complex and complicated network of organisations,

it does not help understand the relationships and networks in the detail required to make the analogy effective.

Notwithstanding the lack of an ecological approach, network analysis in defence and security industries, organisations and the relationships does exist: Supply network analysis (Ghanmi et al. 2009); social network analysis for a variety of applications for detection of crime and terrorism (Masys 2013); social network analysis to assess battlefield interoperability (Enos & Nilchiani 2017); and, to identify communications themes (Baird 2017). The most relevant paper to aid this research is Howard et al (2016) as it explores the relationships between different Government departments and suppliers. This begins to identify some of the key actors in the network.

It is the intention of this paper to use ecological terms to classify organisational analysis and enable the ecological analogy to be used much further than has already been evidenced for this purpose. The scope of the analogy is currently the United Kingdom defence companies, organisations and departments. It's envisaged that the same classifications can be applied to other nations and business sectors (particularly security and aerospace); however, those are outside of the scope of this paper.

Method

Extending the analogies shown in Table 1 (Keoleian et al. 1995) and Shaw and Allen (2015), the terms identified are defined and appropriate defence-related types of organisation, and then specific organisations, are identified from the United Kingdom defence spectrum. These are compared against the ecological definitions provided by that sphere of science and subjectively assessed for their relevance. Additional relevant terms not included in Table 1 are also identified and included in this assessment of terminology. The subsequent hierarchy of terms and associated examples if then provided in conclusion and the relevant analogies are examined.

The findings are summarised within Table 2.

Research and analysis

The basic structure of the ecosystem set out in Table 1 (Keoleian et al. 1995) provides a hierarchy with which to start our taxonomy: Ecosphere, Biosphere, Biogeographical region, Biome landscape, Ecosystem, Organism.

Ecosphere

The highest tier within the hierarchy identified by (Keoleian et al. 1995) is *Ecosphere* and is compared with the equivalent industrial organisation of the International Organisation for Standardisation (ISO) and the global material and the whole world population for social organisations. The biological definition is the whole of the planet and all that inhabit it, along with the factors that affect those organisms (Cleveland & Morris 2009). Given the nature of the approach chosen, it would appear that the selection of the ISO as the equivalent is not in line with that of the other definitions identified in the research: It is the selection of an individual organisation that does not align with the biological definition; however, the social equivalent identified of the whole world population is aligned.

Biosphere

Two ecological definitions of the *biosphere* are provided: The first relates only to the living elements of the *ecosphere* whereas the second is the regions of the earth and its atmosphere than can support life (Cleveland & Morris 2009). The industrial equivalent considers this next tier to be cultures in social organisations, trade associations for industrial organisations and sectors in industrial systems (Keoleian et al. 1995). As with the *ecosphere*, the definition for industrial organisations does not align; however, the industrial system equivalent (sectors) could align with global-level sectors.

Biogeographical region

Distinct areas of the earth than can support specific sets of animals and plants are identified as *biogeographical regions* (Huggett 2011). The equivalents identified for industrial organisations and systems are corporations and companies (Keoleian et al. 1995); however, these fail to recognise the geographical nature of organisations. Therefore, it is more appropriate to consider the biological definition as a stronger relationship and consider the industrial equivalent to be similar to classifications of developing and developed countries (World Trade Organization 2017) or those

similar to the historic definitions of the first, second and third worlds (One World Nations Online 2017). The cultures, and particularly corporate cultures, of these different areas would appear to support that classification.

Biome landscape

The level of descriptor for industrial organisations is Divisions, whilst industrial systems are the Product Systems (Keoleian et al. 1995); however, given the deviation at the *biogeographical region* level, these continue to be inappropriate classifications. Shaw and Allen (2015) examine the *biome* perspective and consider that they "occur at different scales which are based upon supportive cultural, regulatory and even tax 'climates'". This definition provides an opportunity to consider those other ecosystems that exist in similar 'climates' to that of the defence ecosystem to exist within the same biome. From a UK perspective, this would include the aerospace, security and space sectors. The inter-relationships are established through bodies that represent these areas as well as defence. They include the Aerospace, Defence, Security and Space Group (ADS Group), the Defence and Security Knowledge Transfer Network and the Aerospace and Defence sector grouping on the Financial Times Stock Exchange.

Ecosystem

This term is where the analogy expands from. Considered to be specific teams or life cycle stages in industrial organisations and systems (Keoleian et al. 1995), other literature reviewed identifies this as "an economic community supporting by a foundation of interacting organizations and individuals" (Moore 1996). This is wider than the traditional view of an industry and it may incorporate elements of more than one industry (Moore 1993; Nuseibah & Wolff 2015). This aligns with the concept of a 'defence *ecosystem*'.

Community

Shaw and Allen (2015) identify a *community* perspective from which to study innovation ecosystems. The community is defined as interdependent populations (Oxford Dictionaries 2017a) and as organisations that work closely together but with different roles. They are not merely greater numbers of *species* or *populations*; however, they have the same or similar business models and competition happens within *communities* (Shaw & Allen 2015). When analysing the variety of

organisations with the UK defence ecosystem, there are distinct *communities* that exist. The Defence Industrial Triptych (Heidenkamp et al. 2013) identifies three distinct roles for Government as customer, sponsor and regulator. Customer and regulator are easily understood; however, 'sponsor' has different meanings depending upon the specialism. In this case, the 'sponsor' is considered to be the 'enabler' and provides policies and funding so the defence suppliers can operate without requiring a specific product for the Government to become the customer. Therefore 'enabler' could be split into separate 'policy' and 'funding' *communities* as these are the different business models that surround them. Other similar organisations provide policy in the form of standards and information, similar in style to regulation. The same can be said for funding, which may be available from non-government sources, such as research and development funding from academic sources. This example demonstrates that the same organism (in this case the UK Government) can live across different communities as in ecology.

Thus the four distinct communities in defence can be classified as: Suppliers; Regulators; Customers; and, Funders.

Population

Groups of similar organisations that operate similar business models and may increase or decrease in number depending upon the environment in which they are currently operating and the resources available to them (Shaw & Allen 2015). Within UK defence suppliers, examples include defence primes, key suppliers and small-to-medium enterprises (SME) (Ministry Of Defence 2012). They have distinct differences in their business models, yet would all be part of the supplier community.

Species

Where two or more *organisms* can interbreed without creating a mutation (Oxford Dictionaries 2017d). As an industrial example, this would be the business model remaining unchanged; however, if the business model changes then the *species* of the *organism* would change (Shaw & Allen 2015). This may happen through innovation or expansion into other areas, industries or specialisms.

Specific defence applications may be the merger of two SMEs that provide additional capability so the business model can change and they can operate in another

ecosystem. Another example may be the merger of numerous SMEs to such an extent that their size means they change *population* to a key supplier (i.e., that without SME status).

Species could be direct competitors in a supply chain and may be able to replicate another organisations work without changing its business model to do so.

Organism

The *organism* is originally conceived as the individual worker or unit step within the industrial organisation and system classifications (Keoleian et al. 1995); however, it is more appropriate, given the definitions provided already, to identify this level as the organisation, company or other distinct entity within the *ecosystem*. The interdependent parts of an *organism* (Oxford Dictionaries 2017b) represent the different typical functions and groups of an organisation, such as internal management, finance, quality, and safety.

Value dominators

Identified by Nuseibah and Wolff (2015) as the "underperformers who intend to maximise their profits by minimal effort from their side" they are a type of *organism* that seeks to have the greatest return on their investment and minimise the use of their own resources. They represent a risk to the *ecosystem* and their drain on the resources may collapse the entire system (Iansiti & Levien 2004). An ecological example of this would be a predator that fails to support the *ecosystem* in return.

Keystone species

These *organisms* aim to improve the performance of the ecosystem through structures and systems that that have the assets to influence. Iansiti and Levian (2004) identify Microsoft and Wal-Mart as examples of these where the rest of the *ecosystem* is dependent upon their existence for continued survival. Should they fail then it would have catastrophic effects across the whole *ecosystem*. They facilitate collaboration and innovation (Nuseibah & Wolff 2015).

Niche

A type of *organism* that has a specific focussed activity that brings value to the *ecosystem*. This is the most innovative type of organisation and the most valuable

(Iansiti & Levien 2004). They are at risk if another *organism* is operating with the same focus and potentially using the same resources (Daintith & Martin 2010).

Cell

At the most granular level, the *cell* is similar to the members of staff, or other types of worker, in an *organism*. *Cells* can operate independently and can be single-*cell organisms*, representing owner/operator businesses. *Cells* in the form of bacteria can move between *organisms* in a similar way to which staff can move between organisations.

Other terms worth defining through an ecological framework include *genome*, *biotic*, and *abiotic*. These are not part of the hierarchy of ecological terms and are therefore do not appear in Table 2.

Genome

The *genome* is the code which controls the development and behaviour of the *organism* (Daintith & Martin 2010); therefore, it is considered similar to the business model of the organisation (Shaw & Allen 2015).

Biotic and abiotic

The living elements of an *ecosystem* are classified as *biotic* (Daintith & Martin 2010) and include the *organisms*, *populations* and *communities*. In contrast, the *abiotic* elements are the non-living environmental factors such as the soil and water that the *ecosystem* needs to survive. In the business analogy, the *biotic* elements are the organisations and people, with the *abiotic* elements the infrastructure that exists to support their business activities.

Table 2 - Comparative analysis

Tier	Term	Biological definition	Industrial definition	Defence equivalent (examples only)	UK defence example
1	Ecosphere	The planet and all the living organisms that inhabit it, along with the environmental factors that affect them. (Cleveland & Morris 2009)	All global organisations and all elements that support those organisations.	As for industrial equivalent.	Not applicable.
2	Biosphere	Those regions of the earth and its atmosphere that are capable of supporting life; the earth's living system as a whole. (Cleveland & Morris 2009)	Multi-national, global-level industry sectors. Only where populated regions enable economies to exist.	All global industrial ecosystems combined.	
3	Biogeographical region	Regions (in biogeography) are spatial units of varying scales carrying comparatively distinct sets of animals and plants. (Huggett 2011)	1. Organisations within the first, second or third worlds. 2. Organisations within the developed or developing regions.	1. Defence organisations within the first, second, or third worlds. 2. Defence organisations within the developed or developing regions.	All UK-based organisations would be classified within the 'first' or 'developed' biogeographical regions. There may be interaction with other regions.
4	Biome landscape	"1. A complex biotic community existing in a given region, produced by the interaction of climatic factors, living organisms, and substrate. 2. Specifically, a community that has developed to climax vegetation, such as tundra,	Ecosystems that operate within the same regulatory, cultural or tax environment.	Ecosystems that have similar customer arrangements, export, regulatory and tax structures.	For example, aerospace, security, space and the wider public sector.

		coniferous forest, or grassland." (Cleveland & Morris 2009)			
5	Ecosystem	"an identifiable entity in nature, consisting of a community of living organisms and their surrounding environment of air, soil, water, mineral cycles, and so on, which they interact with and affect." (Cleveland & Morris 2009)	"an economic community supporting by a foundation of interacting organizations and individuals" (Moore 1996) including its non-living elements, such as infrastructure.	The defence industry as well as the wider organisations and physical infrastructure that support and require its existence.	The UK defence ecosystem.
6	Community	"A group of interdependent plants or animals growing or living together in natural conditions or occupying a specified habitat." (Oxford Dictionaries 2017a)	Interdependent populations that work together with similar business models but may compete with each other.	• Suppliers; • Regulators; • Customers; and, • Funders.	As generic defence equivalent.
7	Population	"A community of animals, plants, or humans among whose members interbreeding occurs." (Oxford Dictionaries 2017c)	Groups of organisations that operate similar business models and those group sizes fluctuate depending on the resources available. They may be represented by trade associations.	• Global corporations; and, • Small-to-medium enterprises; • Trade associations; • Academia; and, • Financial institutions.	• Defence Primes; • Key Suppliers; and, • Small-to-medium enterprises. Trade Associations such as the ADS Group representing their Members.
8	Species	"A group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding." (Oxford	Groups of organisation that operate within similar specialisms and are capable of replicating the work of another	• Electronics organisations; • Engineering companies; and,	These would be direct competitors within the supply chain.

		Dictionaries 2017d)	organisation within the population.	• Specific weapons manufacturers.	
9	Organism	"A system or organization consisting of interdependent parts, compared to a living being." (Oxford Dictionaries 2017b)	The single entity, company, organisation or government department involved in the ecosystem.	• Limited companies; • Government departments; • Non-governmental organisation; and, • Trade Association.	• BAE Systems plc; • Lockheed Martin; • General Dynamics; • Ministry of Defence; and, • Cranfield University.
9a	Value dominator	*Predation*: "An interaction between two populations of animals in which one (the predator) hunts, captures, and kills the other (the prey) for food." (Daintith & Martin 2010)	"Underperformers who intend to maximise their profits by minimal effort from their side" (Nuseibah & Wolff 2015)	These would be a type of organism but not possible to identify specific examples.	This level of detailed research has yet to be completed.
9b	Keystone species	"A species whose impact on its community is disproportionately large relative to its abundance. This is generally because it alone fulfils some crucial functional role in the community, the continuation of which is essential for the survival of numerous other species." (Daintith & Martin 2010)	"consolidate the industry around their value proposition by providing a dominant design or architecture that facilitates collaborations and aids collective innovation in a business ecosystem" (Nuseibah & Wolff 2015)	Defence Prime organisations that lead projects, innovation and programmes.	• UK Ministry of Defence; and, • BAE Systems plc.
9c	Niche	"The status or role of an organism in its environment. An organism's niche is defined by its food supply, predators, temperature tolerances, etc.	Focussed organisations that operate to create value in the ecosystem particularly with innovation (Nuseibah & Wolff	• Defence research and development organisations; • Specific technology developers; and,	• Defence and Security Knowledge Transfer Network.

		Two species cannot coexist stably if they occupy identical niches." (Daintith & Martin 2010)	2015).	• Knowledge transfer networks.	
10	Cell	"the fundamental microscopic unit of which all living things except viruses are composed, consisting of a nucleus and cytoplasm and bounded by a membrane; the minimal structural unit of life that is capable of functioning independently." (Cleveland & Morris 2009)	An individual worker within an organisation.		

Discussion

The classifications identified in Table 2 are based on the subjective comparison of economic definitions against ecological terminology. There will be characteristics that are not applicable to be part of the analogy; however, there is value in using these terms to help demonstrate the evolutionary and organic nature of business activities. It provides granularity beyond that usually used when describing a system as an *ecosystem*. Figure 1 provides a visualisation of the hierarchy established, showing generic examples of a defence *ecosystem* in brackets.

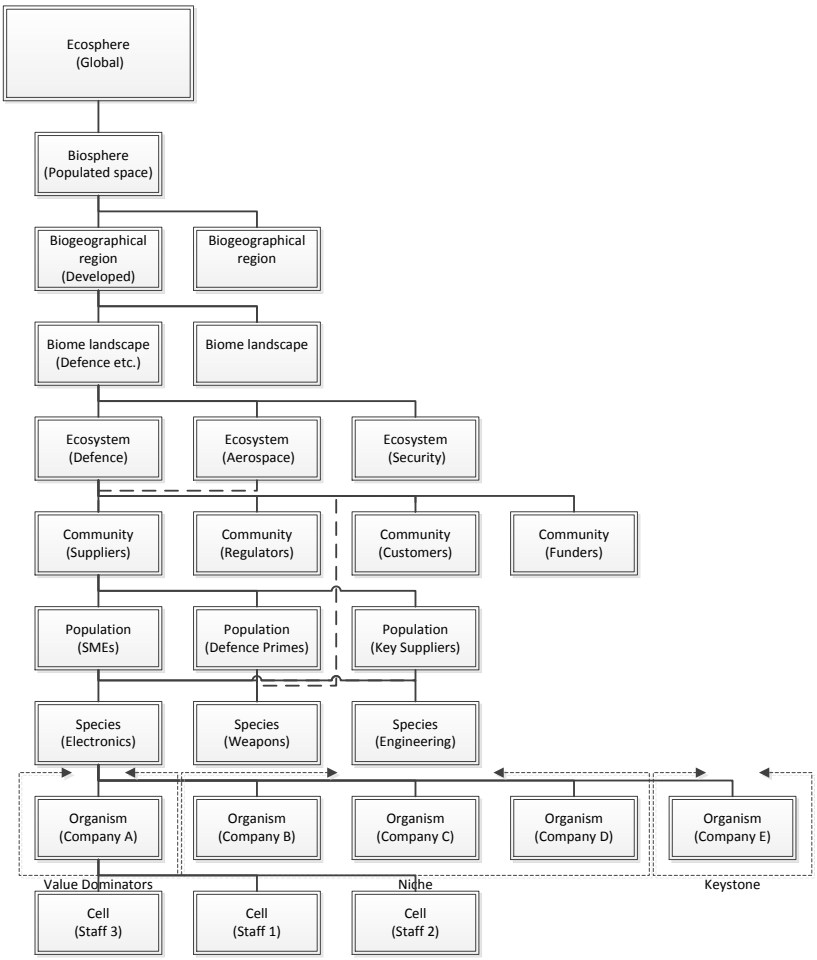

Figure 1 - Ecological hierarchy

Continuous refinement of the approach will be required as organisations are classified into this system. There may be additional ecological terminology that can be translated into the business environment, and vice versa.

Challenges exist in classifying organisations across multiple communities and populations. They will also exist in multiple ecosystems. However, this is not

dissimilar to nature and the same *organism* may exist in multiple *ecosystems* and it is possible that it will have a different role in each. The hierarchical approach may also limit the classification of particular *organisms* to a *species* as the ecological limitations would imply that an *organism* can't be part of two or more *species*; however, this may well render it as a different *species* entirely, and even a single-*organism species*.

Greater transparency and understanding of the relationships in defence industries is current sought after by the UK and US Governments (Fisher 2017; Mehta 2017). Applying an ecological approach will not only provide a visualisation but also a system where behaviours may be understood as well.

References

Anon, 2017. Setting up the defence industrial ecosystem - Livemint. *livemint*. Available at: http://www.livemint.com/Opinion/QCLR2Gpbt2spILUvVyW7sJ/Setting-up-the-defence-industrial-ecosystem.html [Accessed October 7, 2017].

Ausubel, J., 1992. Industrial ecology: reflections on a colloquium. In *Proceedings of the National Academy of Sciences*. pp. 879–884.

Baird, T., 2017. Who speaks for the European border security industry? A network analysis. *European Security*, 26(1), pp.37–58. Available at: https://www.tandfonline.com/doi/full/10.1080/09662839.2016.1267146.

Barnard, F., 1963. Education for management conceived as a study of industrial ecology. *Journal of Vocational Education & Training*, 15(30), pp.22–26.

Cleveland, C.J. & Morris, C.G., 2009. *Dictionary of energy* Expanded e., Elsevier. Available at: https://app.knovel.com/web/toc.v/cid:kpDEEE0001/viewerType:toc/root_slug:dictionary-energy-expanded/url_slug:ecosphere?b-q=ecosphere&b-group-by=true&b-search-type=tech-reference&b-sort-on=default&issue_id=kt007SUTNA [Accessed October 8, 2017].

Daintith, J. & Martin, E.A. (Elizabeth A.., 2010. *A dictionary of science.*, Oxford University Press. Available at: https://app.knovel.com/web/toc.v/cid:kpDSE00001/viewerType:toc/root_slug:dictionary-science-6th/url_slug:predator?b-q=predator&b-group-by=true&b-search-type=tech-reference&b-sort-on=default&issue_id=kt007X8SU8 [Accessed October 8, 2017].

Enos, J.R. & Nilchiani, R., 2017. Using Social Network Analysis to Quantify Interoperability in a Large System of Systems. In *12th System of Systems Engineering Conference (SoSE) System of Systems Engineering Conference (SoSE)*.

Fisher, R., 2017. The Defence Ecosystem. In *DSEI*. London.

Frosch, R.A., 1992. Industrial ecology: a philosophical introduction. *Proceedings of the National Academy of Sciences*, 89(3), pp.800–803. Available at: http://www.pnas.org/cgi/doi/10.1073/pnas.89.3.800.

Frosch, R.A. & Gallopoulos, N.E., 1989. Strategies for Manufacturing. *Scientific American*, pp.144–152.

Garner, A. & Keoleian, G.A., 1995. *Industrial ecology - An introduction*, Ann Arbor: University of Michigan.

Ghanmi, A. et al., 2009. A Framework for the design of a military operational supply network. In *IEEE Symposium on Computational Intelligence for Security and Defense Applications, CISDA 2009*.

Heidenkamp, H., Louth, J. & Taylor, T., 2011. The Defence Industrial Ecosystem: Delivering Security in an Uncertain World. *RUSI Defence and Security Studies*.

Heidenkamp, H., Louth, J. & Taylor, T., 2013. *The Defence Industrial Triptych: Government as Customer, Sponsor and Regulator*, London: Royal United Services Institute. Available at: http://www.tandfonline.com/toc/rwhi20/81/1.

Howard, M. et al., 2016. Performance-based contracting in the defence industry: Exploring triadic dynamics between government, OEMs and suppliers. *Industrial Marketing Management*, 59, pp.63–75.

Huggett, R., 2011. Biogeographical Regions. *eLS*. Available at: http://www.els.net/WileyCDA/ElsArticle/refId-a0003231.html [Accessed October 8, 2017].

Iansiti, M. & Levien, R., 2004. Strategy as Ecology. *Harvard Business Review*, 82(3).

Keoleian, G.A., Koch, J.E. & Menerey, D., 1995. *Life Cycle Design Framework and Demonstration Projects*, Ann Arbor.

Maggiani, V., 2017. Performance Based Logistics and the emerging defence ecosystem. *Defence Online*. Available at: https://www.defenceonline.co.uk/2017/01/11/performance-based-logistics-emerging-defence-ecosystem/ [Accessed October 7, 2017].

Masys, A., 2013. Networks and network analysis for defence and security. In *Proceedings of the 2013 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining - ASONAM '13*. pp. 1479–1480. Available at: http://dl.acm.org/citation.cfm?doid=2492517.2492602.

Mehta, A., 2017. Industrial base war-gaming: Pentagon wants companies to find supply-chain weaknesses. *Defense News*. Available at: https://www.defensenews.com/smr/equipping-the-warfighter/2017/09/28/industrial-base-wargaming-pentagon-wants-companies-to-find-supply-chain-weaknesses/ [Accessed October 9, 2017].

Ministry Of Defence, 2012. *How Defence Works*, London.

Moore, J.F., 1993. Predators and Prey: A New Ecology of Competition. *Harvard Business Review*, 71(3), pp.75–86.

Moore, J.F., 1996. *The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems*, Harper Business.

Newall, P.J., 2014. *Revolving Doors and the Defence Ecosystem: Business Ethics and Identities in Transition*. Cranfield University.

Nordhaus, W.D., 1992. The ecology of markets. In *Proceedings of the National Academy of Sciences*. pp. 843–850.

Nuseibah, A. & Wolff, C., 2015. Business Ecosystem Analysis Framework. In *IEEE 8th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*. pp. 501–505.

One World Nations Online, 2017. First, Second and Third World. Available at: http://www.nationsonline.org/oneworld/third_world_countries.htm [Accessed October 8, 2017].

Oxford Dictionaries, 2017a. community. *Oxford Living Dictionaries*. Available at: https://en.oxforddictionaries.com/definition/community [Accessed October 8, 2017].

Oxford Dictionaries, 2017b. organism. *Oxford Living Dictionaries*. Available at: https://en.oxforddictionaries.com/definition/organism [Accessed October 8, 2017].

Oxford Dictionaries, 2017c. population. *Oxford Living Dictionaries*. Available at: https://en.oxforddictionaries.com/definition/population [Accessed October 8, 2017].

Oxford Dictionaries, 2017d. species. *Oxford Living Dictionaries*. Available at: https://en.oxforddictionaries.com/definition/species [Accessed October 8, 2017].

Paulus-Rohmer, D., Schatton, H. & Bauernhansl, T., 2016. Ecosystems, Strategy and Business Models in the age of Digitization - How the Manufacturing Industry is Going to Change its Logic. *Procedia CIRP*, 57, pp.8–13. Available at: http://dx.doi.org/10.1016/j.procir.2016.11.003.

Rabelo, R.J. & Bernus, P., 2015. A holistic model of building innovation ecosystems. *IFAC-PapersOnLine*, 28(3), pp.2250–2257. Available at: http://dx.doi.org/10.1016/j.ifacol.2015.06.423.

Schiller, F., Penn, A.S. & Basson, L., 2014. Analyzing networks in industrial ecology - A review of Social-Material Network Analyses. *Journal of Cleaner Production*, 76, pp.1–11. Available at: http://dx.doi.org/10.1016/j.jclepro.2014.03.029.

Shaw, D.R. & Allen, T., 2015. Studying innovation ecosystems using ecology theory. *Technological Forecasting and Social Change*. Available at: http://dx.doi.org/10.1016/j.techfore.2016.11.030.

Tsuchiya, K. et al., 1986. Modelling of industrial ecological systems for evaluation of health services. *Ecological Modelling*, 31, pp.329–339.

Tsujimoto, M. et al., 2017. Designing the coherent ecosystem: Review of the ecosystem concept in strategic management. *Technological Forecasting & Social Change*. Available at: http://dx.doi.org/10.1016/j.techfore.2017.06.032.

World Trade Organization, 2017. Who are the developing countries in the WTO? Available at: https://www.wto.org/english/tratop_e/devel_e/d1who_e.htm [Accessed October 8, 2017].