An Evolution-based Approach towards Next-Gen Defence HQ and Energy Strategy Integration

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Abstract: There is an increasing worldwide impetus towards a ‘nil emissions’ industry and energy production. While new technologies and materials have made the concept of renewable energy viable, there are still significant challenges in regards to the transition process in view of balancing the economic, security and environmental aspects. At the same time, the advent of the Internet of (Every)thing/s paradigm and the increasingly dynamic balance of power manifesting itself in various parts of the world have brought about the stringent need to evolve military defence doctrines, starting at the headquarters (command and control) level. As energy and national security clearly display a strong connection, it would be highly advisable to maintain this bond along the life of these two aspects, e.g. by evolving them observing similar principles and in a synchronised manner. This paper describes challenges faced by the two aspects and proposes a way forward that preserves and enhances the symbiosis necessary for a planned energy transition and effective national defence. Thus, while each region and nation will face specific geo-political issues, this paper initiates the process of elaborating a guiding framework (which can then be customised) meant to maintain the above-mentioned critical bond during the various possible transition stages, in a holistic and life cycle-based manner.

1 INTRODUCTION

New technologies and materials have made viable the concept of renewable energy, giving an increasing worldwide impetus to achieving a ‘nil emissions’ industry and energy production. However, there are still significant challenges in regards to the transition process in view of balancing the ‘triangle’ of economic, security and environmental aspects (Umbach, 2012; Weiss, Pareschi, Georges, & Boulouchos, 2021).

On the other hand, the rise of the Internet of (Every)thing/s paradigm (Zdravković, Trajanović, & Panetto, 2014) and the changes in the balance of power worldwide have called for the evolution of military defence doctrines, starting with the headquarters (command and control) level. Energy and national security clearly display a strong connection (Blackburn, 2018; Flaherty & Filho, 2013; Hughes & Long, 2015), which should be sustained along the entire life of these two areas. This can be achieved by evolving them in a synchronised and coordinated manner, while observing similar architectural principles.

This paper aims to initiate the process of creating a framework (customizable for specific geo-political settings) meant to maintain the critical symbiosis during the various possible stages of transition, in a holistic and life cycle-based manner so as to ensure a planned energy transition in sync with an effective transition to a next-generation national defence.

This paper uses Energy Transition as an important example of the fact that effective national defence is not possible unless the country maintains a resilient and agile critical infrastructure (which includes multiple systems, such as various energy systems, communication and cyber, manufacturing, logistics, transport, etc.). The transition model presented in Section 2 is intended to generalise over all of these systems, including defence (Section 3).

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2 TRANSITION STRATEGIES: THE ELECTRICITY ENERGY MARKET EXAMPLE

Discovery of new, cleaner and more efficient energy sources and the required transition based on new technologies of production and use have always been present throughout history. Currently, the transition encompasses fossil sources of energy giving way to so-called renewables, which underpin the solution to tackle climate change and water and air quality, as well as to build a more resilient sovereign capability to meet demand.

2.1 State of the Art and Challenges

Ambitious energy transition targets have been proposed by governments worldwide; while global action is paramount as we all share the same environment, each region faces different geo-political and economic issues. Therefore, generic high-level tools and roadmaps such as those proposed by the World Economic Forum (WEF, 2018) and the International Renewable Energy Agency (IRENA, 2018a) translate into a variety of strategies applicable in view of the economic development level of regions and the nature of the energy infrastructure (Edenhofer, 2011).

Importantly, energy transition becomes an increasingly complicated endeavour as it moves between progressively more complex levels of energy production, storage and use, and thus must be supported by more involved technology and also policies surrounding this change. This is an expected effect, long recognised as the 'requisite (and higher) variety that must be displayed by a system controlling another complex system (Ashby, 1958) so as to be able to cope with its possible states. In addition, energy transition can now more than ever evolve in a non-linear but also unpredictable manner due to factors such as the Internet of Things (IoT), fragmentation of the energy system (WEF, 2017) and mobility transformation. Moreover, certain local factors may determine an accelerated transition in some areas (IRENA, 2018b). We therefore witness a change to an energy *System of* Systems (SoS).

2.1.1 Hydrogen

Hydrogen as a contemporary energy disruptor deserves a special mention. Thus, the (re-)appearance of hydrogen as a viable source of energy in the context of technological advances has brought additional complexity to the energy transition challenge from multiple points of view such as political, economic, geo-strategic etc (Staffell et al., 2019). This is because hydrogen holds the promise of a renewable, clean and efficient source of energy (IEA, 2019) which could give the economic and military edge to a region or nation (Pointon & Lakeman, 2007). The typical phenomenon of innovations in the military domain spearheading application in the industry (with varying degrees of delay (Buzan & Sen, 1990) is already manifesting in the hydrogen area (Narayana Das, 2017).

The transition to a hydrogen-based economy presents some specific opportunities and challenges, such as the ubiquitous availability of the raw material or the decision on whether to use existing infrastructure with some authors calling on a 'fresh start' so as to avoid inheriting systemically ill-designed energy infrastructure paradigms (Blackburn, 2018; Steen, 2016).

All of the above facts clearly spell out a requirement for adequate strategies based on flexible methods and architectures appropriate for various local conditions. This strategy must ensure a steady supply of suitable short-term steps that contribute to a stable long-term change path. The main challenge to energy transition is an out of control random transition in leaps and bounds.

2.2 Transition Planning: An Enterprise Architecture Approach

The design of the future integrated Energy System of Systems structure must take a holistic perspective, considering how the life cycles of contributing systems relate to each another. One must consider two essential relationship types in this perspective; firstly, there are the *operational* relationships enabling the independently controlled participating systems to work together so as to fulfil a *joint mission*. This encompasses the necessary functions of the energy SoS and the required non-functional requirements. Secondly, one has to analyse the relationships allowing the systems in question and their socio-technical environment to influence each other's evolution *in time*.

This leads to the need to a) adopt a life cycle-based, enterprise reference architecture which includes a comprehensive modelling framework (MF) and b) to clearly distinguish between the concepts of *atemporal life cycle* phases and a time-based *life history*. This is necessary in order to be able to represent all *necessary* decision-making aspects as views of a comprehensive repository of system models, covering both recurrent and unique relationships across the SoS of interest. The manner the above endeavour can be performed is described in the following section.

2.2.1 Modelling of the Transition

Modelling a system of interest during its entire life (as deemed desirable in this case) may be performed considering each 'phase' of its life cycle at various levels of abstraction, depending upon the level of concrete detail required. In this context, a 'phase' is understood as a set of activity types necessary to develop these models and their descriptions. This paper makes use of ISO15704's (2019) architecture modelling framework constructs featuring intrinsic life-cycle phase representations so as to depict *perspectives* reflecting typical stakeholder *concerns*. This MF differentiates between the mission fulfilment and the management and control tasks of a system, whether partially or fully automated (see Figure 1). This feature is very well suited for both domains to be modelled, namely energy transition management and Defence Command and Control.

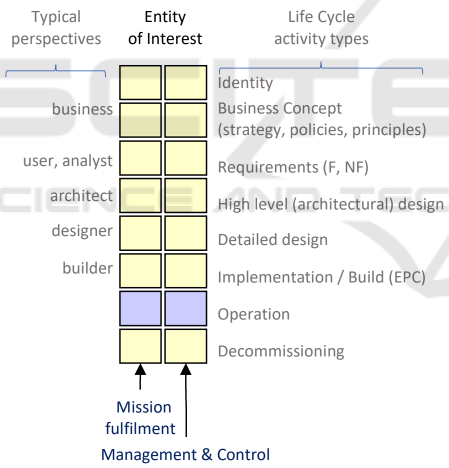

Figure 1: Modelling scope of an entity of interest vs typical stakeholder categories (perspectives, based on ISO15704 Annex B (ISO/IEC, 2019)).

The MF generally abstracts from the flow of time; instead, it represents the fact that various aspects of the entity of interest must be defined by *some* stakeholders. Importantly, if all stakeholders are internal, then the modelled system is able to completely *(re)design itself* and its management is in full control of the system's destiny.

Typically, the redesign capability (and thus the system's *agility* (Dove, 1999)) is limited or non-existent, as its management has multiple constraints (policies and laws, internal or external capability limitations, and so on). It is therefore important to model and understand the desired responsibilities and authorities (and juxtapose these against capabilities necessary for one entity to influence or dictate one or more of these aspects of other entities). The *range* and *role* of the various constructs available must be understood in order to ensure the feasibility of a long-term energy transition strategy and plan.

2.2.2 Dynamic Business Model

The modelling constructs covering the entire scope of the entity of interest's life cycle (see Figure 1) can be used to create a 'dynamic business model' representing life cycle relationships underpinning a transition strategy and plan a transition of the present business architecture ('AS-IS') to the envisioned future state ('TO-BE'). In order to do this, one must first identify the entities or systems of interest in the transition planning, which will populate the business model. Such entities may be (using for example the Australian electricity energy market):

1. Regulators:
   - Federal Government
   - National Energy Regulator (NER)
   - Australian Energy Market Commission (AEMC, including former COAG Energy Council functions)
   - Energy Security Board (ESB)
2. National Electricity Market (NEM)
   - Australian Energy Market Operator (AEMO)
   - Energy Production, Transmission, Delivery and Retailers
   - Australian Renewable Energy Agency (ARENA)
   - Producers, Consumers (note that some may be both, i.e. prosumers (Leal-Arcas, Lesniewska, & Proedrou, 2018)).

These entities and their life cycle relationships are then represented using the construct defined in Section 2.2.1 and Figure 1, as depicted in Figure 2. Note the important fact that a Programme and its Projects are treated as 'first class' entities in this model.

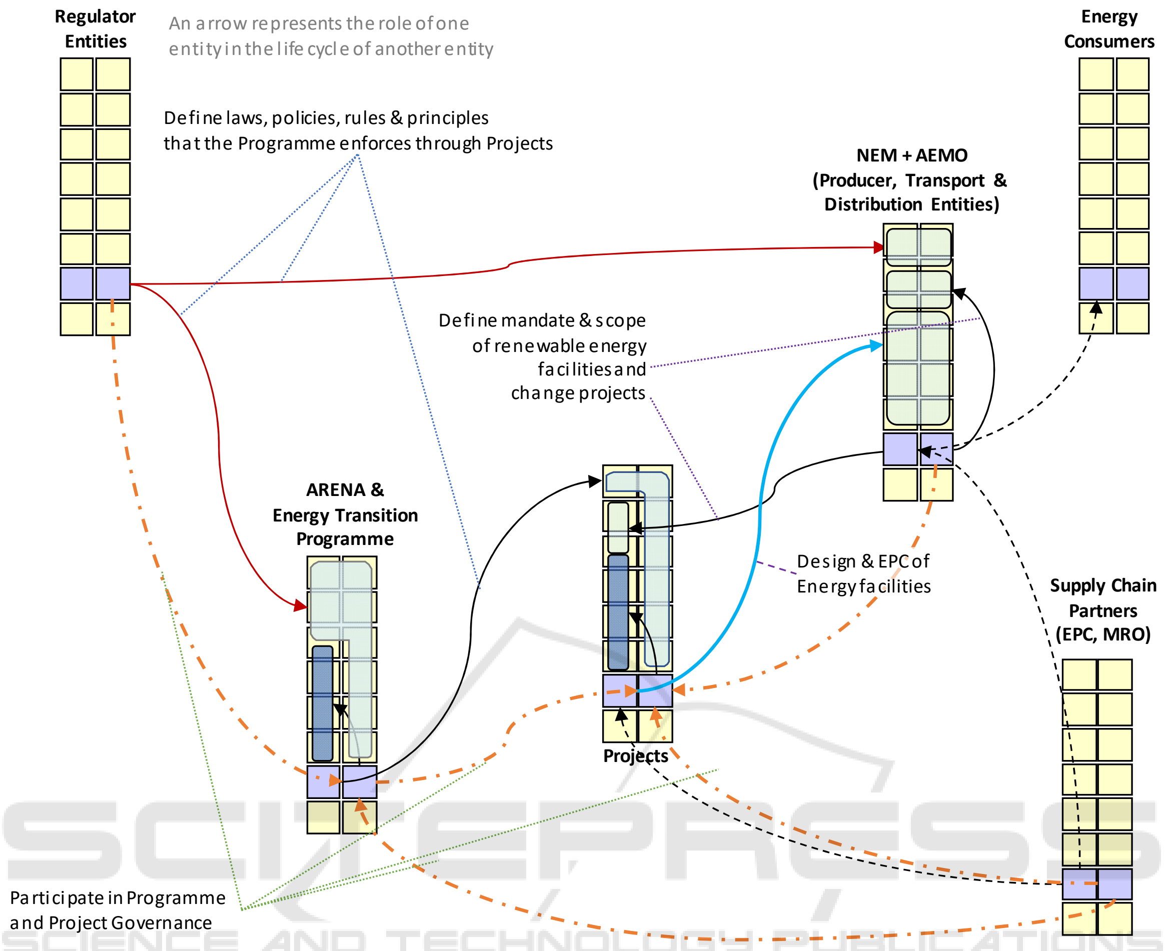

Figure 2: Coordination of transition policies and principles.

Figure 2 shows that the mechanism to coordinate the multiple Projects involved in energy transition is administered by a Transition Programme that decides on supporting and coordinating them as they make changes to the National Energy Market (NEM) participants. The principal task of the Transition Programme is to coordinate and synchronise the investment, typically based on public-private partnerships.

3 TRANSITION STRATEGIES: '5TH GENERATION' DEFENCE EXAMPLE

The spread of IoT and artificial intelligence (AI)-based autonomous agents is having an increasingly widespread impact, with the battlespace concept and the Command and Control (C2) in charge being no exceptions. Importantly, proven doctrines and strategic theories may no longer work in a hybrid, AI-enhanced environment (Benson & Rotkoff, 2011); this calls for new and innovative concepts that are likely to transform C2 into a *socio-technical and cyber-physical system-of-systems*. For the above reasons, it is imperative that the analysis of such a transformation involves a construct that can encompass and master technical but also social aspects, and among others, is able to natively represent the *extent of automation*, i.e. boundaries of human and machine domains (essential e.g. in the case of hybrid agents).

C2 failures, directions of improvement and future trends have been investigated in the relevant literature. Thus, Vassiliou et al. (2015) identify (interrelated) failure pressure points, such as an inappropriate C2 approach, inadequate systems architecture, and a lack of agility, trust and interoperability. These issues, already complex and currently not properly addressed (ibid.), are likely to be exacerbated in the context of the major changes ahead and thus should form part of the requirements in the quest for a new C2 paradigm. Thus, it may be in fact the case that unresolved issues are carried on to a next generation HeadQuarters (HQ) before being addressed. This is typical of an accelerating pace of technological advances that increasingly leaves the legal, ethical (e.g. regulatory (Marchant, 2011)) and social (such as *trust* (Brown, 2020)) aspects behind.

3.1 Next Gen HQ Defence Concepts

In the process of characterizing the future (TO_BE) state for the 5th generation HQ, it would be very helpful to define some important features for this state. Yue et al (2016) have attempted to define essential properties of an AI-enhanced HQ supporting operations in a complex battlespace; this was called '5th Generation HQ', based on analogies made with other related Defence areas. They have defined managed cyber visibility, organisational agility, advanced C2 decision systems, network information fusion and versatility as essential characteristics. The question is: how do these translate in terms of the entities participating and interacting within the transition to a 5th Generation HQ?

According to Yue et al. (ibid.), managed cyber visibility in the case of HQ refers rather to security and required footprint and less to stealth; this may translate in advanced encrypting technology, communications governance comprising a separate evolvable and resilient network infrastructure, properly managed and defended.

C2 agility becomes paramount as battlespace complexity increases; thus, for any given scenario there should be a matching organisational structure able to manage it as per Mintzberg's theory (1979), also observing the above-mentioned requisite variety requirement (Ashby, 1958). Hence a 5th gen HQ should display *organisational agility.* This could e.g. be based on a knowledge repository of possible organisational forms out of which the suitable format could be chosen, involving sudden transitions from centralised to distributed C2.

In this sense both Operations and Missions are 'Virtual Enterprises' (VEs) (Camarinha-Matos, Pereira-Klen, & Afsarmanesh, 2011) created and re-created on demand. The VE is the organisational HQ structure required, the Headquarters Joint Operations Command (HQJOC). Notice the requirement for a double loop of generating the requisite organisational structure both on the HQJOC and missions' levels (see Figure 3).

In theory, the missions are created as required (including missions to project forces) (for simplicity this is not shown in the figure): there are two things to be created (by configuring platforms and personnel for mission fulfilment, and by configuring mission command – which of course would rely on pre-designed 'building blocks'). However, mission command (which in the extended sense consist of all agents involved in C2, down to the level of the individual warfighter) is now in charge of negotiating (possibly sudden) changes in C2 structure. The first loop is this self-configuring ability, while the second loop is the one between HQJOC and the Mission, whereupon HQJOC has the ability to reconfigure the mission (including the Mission Capability and Mission Command).

Evolved Situation Awareness (SAW) (Niklasson L. et al., 2008) is at the core of advancing C2 decision systems both in HQJOC and Mission Command. As the number of sensors and thus available data increases and warfare is likely to increasingly become accelerated, the time available for decision-making is continuously contracting; therefore, appropriate decision support systems are paramount. In addition, established doctrines and theories may become unable to cope with the new situations; hence, new (or the re-consideration of existing) theories, logic and SAW paradigms (Goranson & Cardier, 2013; Noran & Bernus, 2018) is imperative, as technology advancements alone are necessary but not sufficient to enable 'next generation' leaps (Fletcher, 2015).

In the IoT environment, more and more objects are designed with native networking capabilities. Manipulating and storing information is paramount to SAW, both for individual warfighters and the entire battlespace. However, proliferation of the network-enabled participants brings issues of (among others) bandwidth, prioritisation, noise and interoperability, which become essential enablers (or inhibitors) of the required network information fusion. Ongoing work on 'universal' interoperability (interoperability as a property, IaaP) (Noran & Zdravković, 2014) is rather in its infancy and raises the important issue of security (e.g. undesired / unintended interoperability with foe devices). Interoperability at organisational level is also a key enabler of agility or versatility, although it may conflict with another desired non-functional requirement, namely resilience, due to the link to the need to maintain integration. Thus, a balance must be designed into the future state whereby a balance is achieved between integration, resilience and interoperability for each specific battlespace scenario.

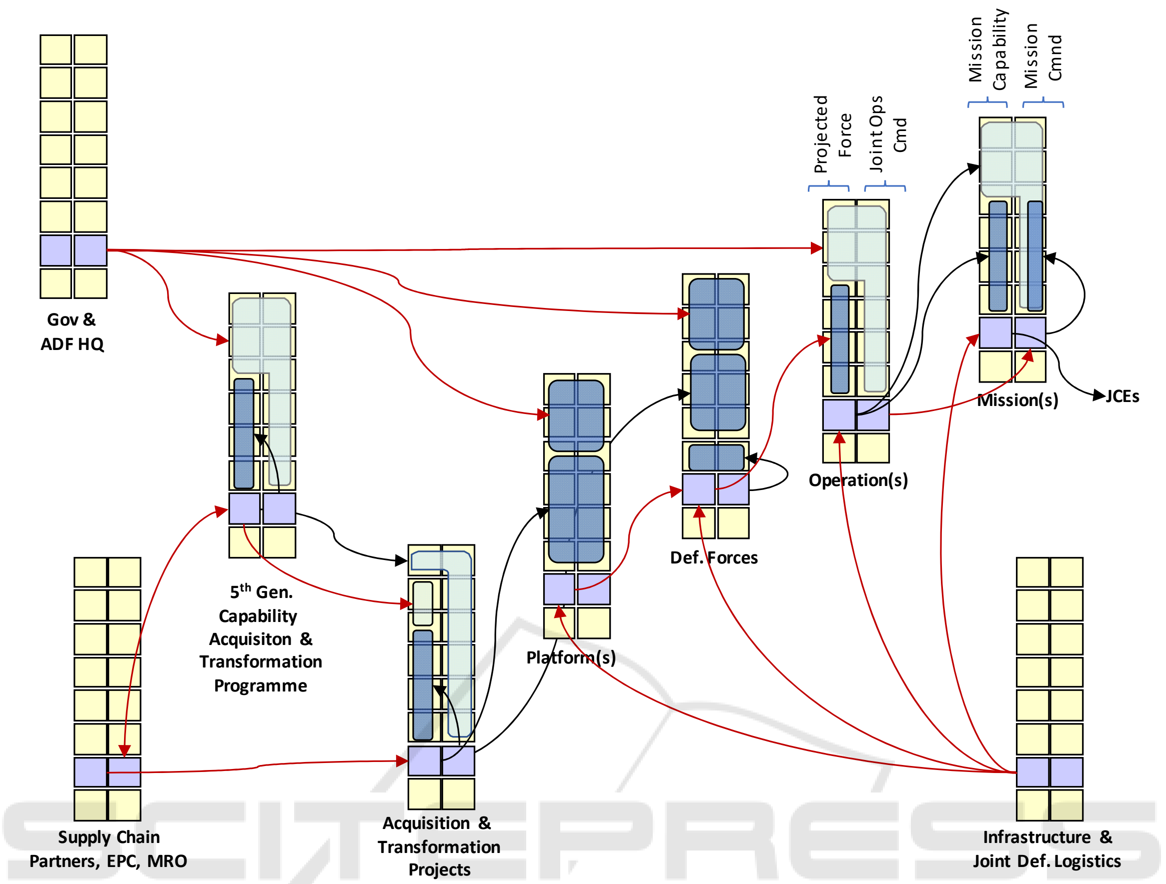

Figure 3: (Dynamic business model of the) relations between the entities relevant to 5th Gen HQ transition.

3.2 Transition Modelling: Dynamic Business Model

Since the framework adopted allows natively representing all the essential aspects in an integrated manner, the authors use the same constructs subsumed by it (see Figure 1). These are used to create once more a dynamic business model featuring life cycle relationships reflecting the desired systemic properties previously described. The entities or systems of interest populating the business model could be in this case:

- Government / Defence HQ (including Capability Acquisition and Sustainment Group, CASG)
- The composing Forces and Platforms
- Joint Forces network
- Operations
- Missions
- Defence Logistics
- Other supporting Entities and Systems;
- Engineering Procurement Contract (EPC) / Maintenance Repair Overhaul (MRO) supply chains.

Figure 3 shows a dynamic business model of the relations between the entities relevant to a planned 5th Gen HQ transition.

The model assumes that preparedness building for such agile C2 starts with the definition of architectural policies and principles by Government and ADF HQ, on the level of capability acquisition and transformation programmes which in turn enforce these through co-ordinated acquisition and transformation projects. Some of these projects are aimed at platforms and some at the transformation of Defence Forces and HQJOC; the latter two are implied but for simplicity not explicitly shown in Figure 3, as the detailed exposition of this so-called ‘dynamic business model’ is beyond the scope of this paper.

4 ENERGY AND NEXT GEN HQ EVOLUTION

4.1 The Link between Next Gen HQ and Energy Transition

The link between Defence Force evolution and Energy transformation is symbiotic as Defence needs energy to operate (Samaras, Nuttall, & Bazilian, 2019) and energy resources, production, storage and distribution need protecting by Defence (Hinsch & Komdeur, 2017). In the context of climate change and shifting global balance of power, many countries and regions re-assess their weaknesses in regards to either energy resources, production, storage and distribution and aim to correct the situation by achieving energy independence in all aspects. Thus, some countries produce raw fuel but no longer process it due to various reasons (political, economic etc. (Blackburn, 2014)), while others import raw fuel and export the processed products due to scarcity of fuel resources (Parthemore & Rogers, 2010).

The above scenarios are fraught with danger as there is a lack of resilience and preparedness expressed through an independent complete supply chain that can ensure a *minimum* energy supply to survive and defend oneself at least temporarily. E.g., for the first scenario, minimal processing capabilities should be available and kept on stand-by so as to be activated when necessary (and properly defended).

Blackburn (2018) draws an analogy between Defence and Energy approaches by using the Generations Concept, whereby the latest (5th) attempts to adopt an integrated Systems of Systems (Maier, 1998) approach. This similarity is clearly warranted, as national security (underpinned by an operational Defence) is intimately linked to economic and energy security and as such, proposed strategies should promote their *concerted evolution*, as also advocated by many authors (Foxon (2011), Safarzyńska et al. (2012), Cherp et al.(2018), etc.). Planning can be conceived as a type of command and control materialised on various lengths of time (called *horizons* by Doumeingts et al. (1998)). Hence one can in fact reason about synchronizing planning and C2. Importantly, adopting such a stance would have the potential to turn energy transition planning into an agile *endeavour* with all its components adapting to technology advances and current situation – here for example, global / regional military balance.

In a side-by-side comparison of C2 evolution and energy transition, one can observe the following:

- On the one hand C2 needs to adapt to- and adopt new technologies and paradigms (e.g. autonomous agents) to cope with- and out-perform adversary manoeuvres (such as in their Observe-Orient-Decide-Act (OODA) loop as described by Osinga (2006)), so as to ensure operational and effective defence and thus to achieve the desired Joint Capability Effects (JCEs);
- On the other hand, similarly, energy transition strategies need to adapt to new technologies in order to cope with changes in the energy market, 'prosumer' (Leal-Arcas et al., 2018) usage habits, mobility and importantly due to shifting economic and military balance of power affecting the national energy strategy. This will allow it to generate effective directives forming short term (operational) steps that contribute to a stable transformation path (Noran, 2019). Note that energy provision (in its various forms) is one of the main elements of the Infrastructure and Joint Defence Logistics supporting all of the entities listed in Figure 3.

As one can see from the above, there are clear connections and overlaps between the aspects that need to be heeded in the operation, *but also in the evolution* of the two domains. This brings about the need for an integrated approach along the entire life of the participant entities, rather than limited to a snapshot reflecting only a particular life cycle phase of each.

While Section 2 was concentrating on electricity energy transition (for illustrative purposes), a similar transition model can be drawn up for the rest of the energy sector, such as fuel (petrol, diesel, aircraft fuel, hydrogen, etc) and for any other critical infrastructure.

4.2 Concerted Evolution Modelling

The authors will use the same modelling constructs as previously in order to model a strategy to evolve Energy towards a renewable form, and Defence HQ towards a 5th generation paradigm. This is useful in order to reason about and start the process of concerted evolution; thus, decision-makers can see clearly what entities (system components) are involved and importantly, *in which phase of their life cycle,* and whether this influences their command and control- or product / service aspect.

In examining Fig 2 and Fig. 3, one may realise that some entities in fact belong to a same type of generalised entity (see Figure 4).

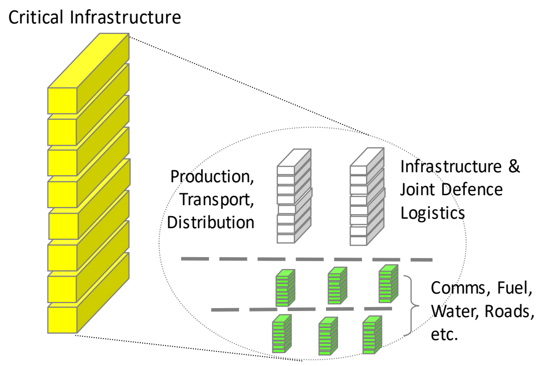

Figure 4: System of Systems depiction using the chosen modelling construct.

Thus, for example the entity in Figure 2 subsumes Producer, Transport and Distribution and the Infrastructure and Defence Logistics entities in Figure 3 are in fact of the same type that could be defined as 'critical infrastructure' (see Figure 4) – and in that sense, the Critical Infrastructure entity is in fact itself a System of Systems.

This applies to several sets of entities from the two figures. Based on this acknowledgement, one can start identifying the necessary interactions between the 'akin' (belonging to the same type) entities previously found. This is illustrated in Figure 5, where such entities are linked by a few sample relationships which are desired in an 'concerted evolution' TO-BE state. Thus, for example, Gov't and ADF HQ influence the operation of Regulator Entities and vice versa, so that the development and regulation policies are developed in an integrated manner. Similarly, the Energy Transition Programme influences the 5th gen Acquisition and Transformation Programme and vice versa. Note that the influence in this case manifests itself from the operation of the originating entity to a set of life cycle phases of the destination entity. This signifies the fact that the (initial and re-) development of the destination entity is accomplished taking into account the issues brought in by stakeholders of the originating entity. In contrast, in the first example the influences manifested themselves only during operation. This allows to reason and model necessary interactions during the required life cycle phases.

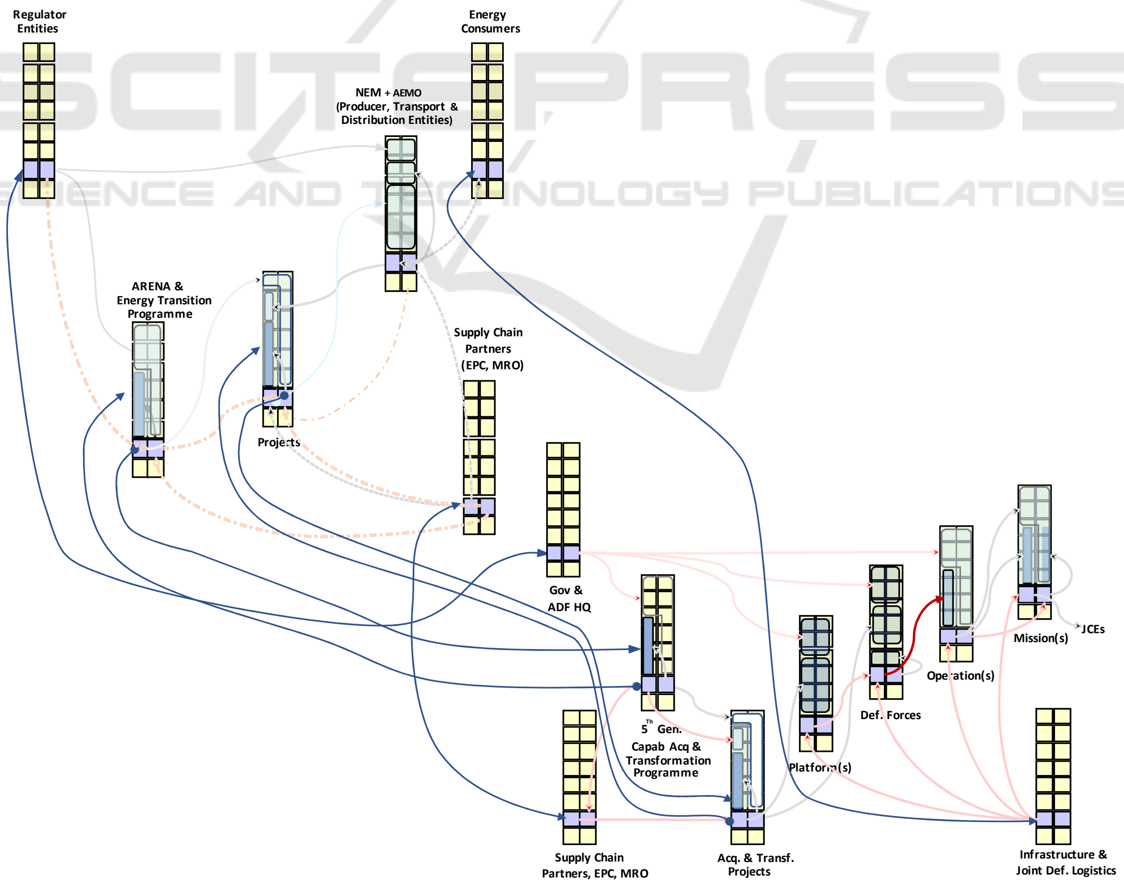

Figure 5: Interactions between energy transition and next gen HQ entities (double headed arrows show reciprocal influence).

The above-described exercise is very useful in allowing stakeholders to reason about, identify and structure the necessary links enabling the required concerted evolution of what are in fact subsystems of the same 'critical system of systems' underpinning all other aspects of contemporary life.

5 CONCLUSIONS AND FURTHER WORK

Technology is evolving at an accelerating rate, making new sources of clean energy increasingly feasible and promoting the introduction of AI-enhanced autonomous agents in all aspects of life. The transition to new forms of energy production, storage and usage must be properly managed to ensure security, sustainability and equity. Closely linked to energy security strategies, Defence spearheaded by its C2 must also evolve to take advantage of the new AI technologies so as to cope with a shifting global balance of power.

This paper has advocated a coordinated enterprise architecture approach whereby the development of the two areas is synchronised in a holistic manner considering all necessary aspects and interactions, at suitable abstraction levels and for each life cycle phase.

Further work will seek case studies focused on various areas in order to evolve and detail the approach presented.

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