21st International Command and Control Research and Technology Symposium: C2 in a Complex Connected Battlespace

A concept for 5th generation operational level military headquarters

Topic area: Topic 2 - C2 Concepts, Theory, Policy and Approaches

Authors:

Yi Yue, Defence Science and Technology Group, Department of Defence, Australia
yi.yue@dsto.defence.gov.au

Alexander Kalloniatis, Defence Science and Technology Group, Department of Defence, Australia

Elizabeth Kohn, Defence Science and Technology Group, Department of Defence, Australia

Keywords: Headquarters, concept, autonomous agent

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Yi Yue, Alexander Kalloniatis, and Elizabeth Kohn

Abstract

Operational level military headquarters (HQ) are the brain of a modern command and control (C2) system. It is envisaged that in the near future, artificial intelligence (AI) based autonomous agents will proliferate both within HQs and in a battlespace over which they exercise C2. To integrate such technology effectively may require a complete alteration of a HQ's roles, functions, processes and organisational structures. In order to enable C2 to be conducted in innovative ways in these circumstances, the question "what are key desirable properties of an AI-enhanced HQ, conducive to operations in a complex connected battlespace", needs to be examined. This paper articulates a concept for the future operational level military HQ, which we term a "5^{th} generation" HQ. We apply three lenses to describe the concept. Military HQs have gone through major changes due mainly to technology revolutions since the Napoleonic era, thus the first lens is historical and technological. In air warfare, the latest capability hinges on 5^{th} generation fighters, with similar capability evolutions happening in other warfighting domains, thus the second lens is by analogy with corresponding 5^{th} generation platform characteristics such as stealth and high manoeuverability. Finally an effect lens is used to inspect the desired effects a 5^{th} generation HQ should generate. After describing the 'what', we explore the 'why', i.e. the drivers that generate the requirement for a 5^{th} generation HQ. We also attempt to determine underlying theoretical principles that support our assertions and a 5^{th} generation HQ design should be based upon.

1. Introduction

As the pace of technological advances increases at an unprecedented rate in the information age, the battlespace is undergoing a significant transformation with a ubiquitous presence of networked intelligent devices that possess higher levels of autonomy. In this connected complex battlespace, a Command and Control (C2) system must become a truly sociotechnical system where both social and technological aspects need to be integrated synergistically to guarantee optimal performance. As the brain of this system, an operational level military Headquarters (HQ) deserves particular attention. However, a quick scan of the open literature reveals that research papers dedicated to this topic in the last few years are scarce. This paper attempts to contribute to bridging this gap.

Modern operational level military HQs must accomplish many other missions along with the traditional military one – defeating adversaries in the physical battlefield. Davids et al. (2011) studied a NATO headquarters in Afghanistan and demonstrated how the existing C2 systems, which were focused on kinetic effects, were ill-equipped for the new mission landscape. Vassiliou et al. (2015) analysed historical and experimental evidence of C2 failures and identified four megatrends which will shape future C2 practice.

In addition, it is envisaged that in the near future, Artificial Intelligence (AI) based autonomous agents will proliferate both within HQs and in the battlespace over which they exercise C2. To integrate such technology effectively may require a complete alteration of a HQ's roles, functions, processes and organisational structures.

This paper examines "what are the key desirable properties of an AI-enhanced HQ, conducive to operations in a complex connected battlespace" and articulates a concept for the future operational level military HQ, which we term a "5th generation" HQ. Three lenses are applied to describe the concept in sections 2-5. Military HQs have gone through major changes due mainly to technology revolutions since the Napoleonic era, thus the first lens is historical and technological. In air warfare, the latest capability hinges on 5th generation fighters, with similar capability evolutions happening in other warfighting domains, thus the second lens is by analogy with corresponding 5th generation platform characteristics such as stealth and high manoeuverability. Finally an effect lens is used to inspect the desired effects the 5th generation HQ should generate. After describing the 'what', we explore the 'why', i.e. the drivers that generate the requirement for a 5th generation HQ in section 6. In section 7, we assert the underlying theoretical principles upon which a 5th generation HQ design should be based. Finally we summarise our discussion.

2. 5th generation HQ through a historical and technological lens

Headquarters have evolved both as technologies for improving communication, information flow and providing situation awareness have changed and as new modes of organisation have become available. With every significant technological revolution at a societal level - the industrial revolution and the recent information age revolution - newer ways to organise human activities emerge and these in turn are reflected in military HQs. Specifically, the combinations of new technologies and innovative organisational modes have enabled commanders to exercise varying degrees of centralised control or influence over military forces over larger and larger distances beyond the range of their voice and their sight. In the following sprint through military history we will assume the reader is broadly familiar with the modern staff functions of the Common Joint Staff System (CJSS) and will often refer to historical structures using modern language. Though the developments we outline were manifold and incremental, it is remarkable that we may loosely group them in four great historical periods – that fits in with our theme of 5th generation evolution.

2.1. 1st generation HQ – Napoleon

The story begins, as it often does, with Napoleon and the organisation of his Imperial Headquarters under Louis Alexandre Berthier – frequently touted as the first modern example of a 'Chief of Staff'. The basic functions of Napoleon's staff consisted of the registration and propagation of the emperor's correspondence, the expansion and elaboration of Napoleon's orders, the provision to the Cabinet of the *Grande Armee's* own situation, and the handling of the mass of administrative tasks associated with post, police, supply, hospitals and civilian government – to name but a few (Van Creveld 1985). Contrastingly, information such as arising from Intelligence was channeled directly to Napoleon via his *Maison*. In this respect, one might view Napoleon as his own Operations and Intelligence Chief, while Berthier subsumed the Logistics and Personnel functions. The numbers of personnel employed in these units grew through the period of Napoleon's rule until the rather bloated structure at the time of Waterloo. But these numbers were required as the spatial scale of Napoleon's campaigns grew and the volume and diversity of required information exploded. Often there is a game of chicken-and-egg as to the drivers of change, but we may be confident that Napoleon may never have dreamed of C2 on a continental scale were it not for the existing French system of Semaphore – or optical telegraph - stations developed by Claude Chappe in 1792 culminating in a network across France of 556 stations covering 4,800 kilometres (Durham 2015). These developments form the background to Berthier's articulation in 1796 of his ideas about staff organisation. Not that at his height Napoleon depended completely on the Chappe system (which focused on Paris), as the Emperor was often in the field, rather he relied on the tried-and-tested method of the horse and rider often as an exercise of his Directed Telescope (Van Creveld 1985). For all these developments (and Berthier's service as Chief of Staff coincided universally with Napoleon's victories), there was a degree of mixing of operational and administrative matters in the Imperial Headquarters that Napoleon and Berthier with their respective individual brilliance could handle but which critically overwhelmed the staff at the defeat of Waterloo. In many respects, the great secret of this Commander and Chief of Staff partnership (though Napoleon never viewed Berthier as such) was the ability of the pair to both decentralise control for periods at a time and then centralise at the critical point where armies would converge on a battlefield.

Another aspect of the Napoleonic arrangements, critical for his coordination of forces on such scales, is the role of the *map*. Napoleon had available to him unprecedented qualities of maps based on triangulation, not guess-work. Though Berthier exercised some functions of a Topographical Bureau, expressly for the distribution of maps to subordinates and maintaining a map of the current situation based on reports, Napoleon retained key parts of the service in his *Maison* (Van Creveld 1985). This was consistent with the map as part of military secrets, recognised by such predecessors as Frederick the Great with his secret *Plankammer* in Potsdam (Keegan 2002). For Napoleon, the map was the pivot of his headquarters on campaign. The head of his Topographical service, Bacler d'Albe (successor to the remarkable polymath Lazare Carnot who first established the Topographical Bureau for the purpose of military strategy campaigns in the Revolutionary period) would meticulously prepare the situation map with coloured pins on a large table in the centre of the tent. Arguably this is the first sophisticated *Operating Picture* – not *Common* though, as it was for the Emperor's eyes only. The arrangement of statistical data and associated staff around the table to allow for interactivity and tailoring of the picture to Napoleon's needs completes this function as a genuine socio-technical system in its own right.

The French staff was reformed after its defeat by Prussia in 1871 – on that below – and it is here we begin to recognise structures in the three Bureaux: I: Supply and administration, II: Intelligence, and III: Operations. The fourth *bureau*, Logistics, was not fully recognised – for all its nascence in the Berthier model – until 1917 and World War I (Zabecki 2008a).

2.2. 2nd generation HQ – Prussian-German

The great transformation of Prussian military organisation began with Scharnhorst after the defeat (as so often change is triggered) by Napoleon at Jena. As a consequence of the senior ranks of military command being occupied by often untrained or dilettante Prussian aristocracy (which continued to the end of WWI), Scharnhorst instituted the General War School, later the War Academy, to provide trained staff officers to such Commanders. Through this period the General Staff was responsible for planning and advice to the King, rather than the exercise of operational control. Helmuth von Moltke, on acceding to the Chief of the General Staff in 1857, transformed this situation through the wars of German unification gaining, in 1866, the King's approval to issue orders in the King's name in the war with Austria. By this stage, trains and the electric telegraph (with Friedrich Clemens Gerke's revision of the Morse system in 1848) were playing a role in bridging distance in the movement of men and information; both had played a role in France's defeat by

Prussia in 1871, with Moltke serving as Chief. Crucial to this was the standardisation of War Plans in the Prussian staff – the individual Kingdoms of the Second Reich retained their military staffs for operations – and the singular authority of the Chief.

What is often little appreciated is that, as with Napoleon and the Chappe Semaphore, Moltke served during the period of great standardisation of technology across Germany and the European continent leading to WWI. Indeed, in contrast to Napoleon or Berthier, Moltke was pivotal to this standardisation of time and railway schedules in a speech to the Reichstag in 1891 (Galison 2003).

Though there is little in this period in the advance of the role of the map as serving the Operating Picture for the headquarters over the Napoleonic era, it is notable that Moltke undertook part of his training in the Prussian Topographical Bureau (as did his successor, Alfred von Schlieffen).

Also fundamental to the Prussian-German system through this period, even well into WWII, was the delicate relationship between the Chief of Staff and the Commander typified in the pairings of Ludendorff and von Hindenburg in WWI (admired at the time even by Churchill), or Fritz Bayerlein and Rommel in WWII. It would be easy to view such arrangements as chance pairing of unique individuals, but their frequency throughout the nineteenth and twentieth centuries demonstrates it was part of the system; indeed it was encoded in doctrine. Supporting the authority of the Chief of Staff was the doctrine of *Vollmacht*, by which the Chief may issue orders in the Commander's name even to officers of superior rank. Examples of its use at the strategic level by Fritz von Lossberg in WWI to delegate and retract authority to battalion commanders illustrate it as a mechanism of flexible centralisation and decentralisation (which, however, did frustrate operational level commanders steeped in the doctrine of Mission Command (Zabecki 2008a)).

Turning to the organisation of the staff, we find by the start of WWI the various staff sections enumerated as: I.a Operations and training, II.b Logistics and movements, I.c. Intelligence, and I.d. Ammunition resupply. These were led by a General Staff officer who in turn reported to the Chief of Staff. Administrative and Personnel matters were the responsibility of an *Ober Quartier Meister*. We note the absence here still of a 'Plans' section – operational plans remained the purview of the Chief of Staff alone, in concert with the Commander-in-Chief. The triple structure of Intelligence, Plans and Operations were the basis of the British General Staff ('G-branch') system under a divisional head, with Personnel (A-branch) falling to the Adjutant-General, and Logistics ('Q-branch') to the Quartermaster general.

2.3. 3rd generation HQ – WWI & II British-US

It would be appear churlish to begin the 3rd generation with the late-comers to WWI, the US and their staff system – constructed literally on the ship crossing the Atlantic by Pershing and his Chief of Staff, James Harbord - however, in the labelling G-1 Personnel, G-2 Intelligence, G-3 Operations and G-4 Logistics, we recognise the immediate antecedent of the CJSS. The system fuses the French and British models in the numbering and lettering schemes respectively. After landing in Europe, in view of the state of American preparedness at entry into the war, Harbord created a fifth section – training. In 1921, as US Army Chief of Staff Pershing re-established this structure together with a War Plans Division which folded into Operations again in WWII.

Another development that fits into this period but not within the construct of staff organisation was the solution to the problem of control of naval gunfire with the advent of the Dreadnought battleship in 1905. The Royal Navy, pioneers at this time of naval technology, in 1909-1910 trialed two systems, one by the civilian Arthur Pollen and the other by a British gunnery office Frederick Dreyer. Controversies abound about these trials and the later adoption of the cheaper but technically inferior Dreyer system and the consequences for British disappointment at the Battle of Jutland (Gordon 1996; Padfield 2009). Both employed a form of analogue computer (Pollen's allowed for 'helm-free control' while Dreyer's required manual refreshment of data after course corrections thereby losing time in fast-paced actions). In both cases (and in the German arrangements) an elaborate system of spotters aided by optical devices for range-finding to collect statistical data on splashes, communications around the ship, and target identification were required, which were finally formalised in arrangements of people and technology through a well-defined process (Goldrick 2014) of the fully enclosed 'plotting room' as the seat of situation awareness. This room was separate from the ship's bridge where the Captain or Admiral had visible access to the outside environment, or his private quarters where, in a gentler age, he would have kept his supply of charts. In this room, staff and systems surrounded the 'plot' which presided as a central display (Friedman 2008), representing the environment from a plan view – as in a map – with the ship at the centre. This was the precursor to the radar enabled Plan Position Indicator of the following world war and of Combat Information Centre's (CICs)[1] as a standard facility on a modern warship. For our purposes here though, it is difficult not to imagine Napoleon's tent with its map and surrounding staff and sources of statistical data. However, the imprecision of the technology under battle conditions at the time of Jutland rendered the effort in such a sociotechnical system hard to justify until advances after 1916 (Goldrick 2016). The development of plotting room arrangements was further accelerated with the entry of the US Navy into the war. Its own exercises in fire-control in 1912 were limited due to calmer waters available to the peacetime fleet. The US had effectively adopted the Pollen system by 1917, but lacked training in conditions of the North Sea (Friedman 2008) to convincingly demonstrate the superiority of that system. We argue that this *naval* development of the plotting room represents the fundamental advance over the campaign map with pins and tokens towards the computer-automated Common Operating Picture (COP) in any modern land based headquarters. The advent of radar in WWII further enriched the resultant picture from external non-human sensors.

Returning to land-based organisations and technology, radio had by now become the standard means of threading this system with deployed mobile units. These are, of course, German innovations defying somewhat our classification scheme. In WWI radio was ill-trusted by the Allies and used prolifically and often detrimentally to itself, by the German High Seas Fleet. As van Creveld (1985) points out, the development of robust and cheap radio technology reversed the isolation of commanders and staff far behind troop lines, to such an extent that Rommel's Chief of Staff, the aforementioned Bayerlein often risked capture in the call of duty at the front line.

These innovations were absorbed effectively by British and US forces in WWII. Eisenhower, with his Chief of Staff, Walter Bedell Smith, headed both the US War Plans Division and Operations Branch in the structure Pershing had bequeathed the US military. But apart from the organisation scheme and

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[1] *Apposite* is that a particular CIC, that of the pseudonymous *USS Palau*, was the site of the study by Hutchins (1996) leading to the theory of Distributed Cognition and later Distributed Situation Awareness (Stanton 2006) as the statement that the *entire system* of networked displays, information objects and people – and not the human brains of individuals - constitute the seat of situation awareness.

the rediscovery of mobility, the third generation era may also be characterised by the extended period (compared to the final year of WWI) over which the Allies had to learn how to work together and the (then) two services of the US armed forces discovered how to cooperate in extended theatres. The former, the Alliance, may be characterised as stumbling for all its eventual success. Apart from the strategic level Combined Chiefs arrangement between the British and US service Chiefs, the staffs below them struggled to understand each other (Zabecki 2008b) particularly because of the intricacies of the British G/A/Q branch and associated rank structure. As US involvement in the Alliance increased to supersede that of Britain by the end of the war, the longevity of the G1-G4 staff system was sealed. Further complexity in this was the different allocation of branch functions within the Alliance: Operations clearly were the domain of the Supreme Commander Eisenhower and the staff supporting him; Logistics fell under national authority, something which Bedell Smith could exploit to slow down Patton's perceived reckless race through France (Zabecki 2008b) but not available to him to use in tempering Montgomery's plans for Operation Market-Garden (which Bedell Smith anticipated would fail).

In terms of armed service cooperation, in retrospect we may think that the discovery of Unity of Command in a Joint combatant commander as the result of a rational process, but a degree of serendipity played a role. With the US struggling to come to grips with the Pacific war in 1942, Eisenhower, as War Plans chief, drew up a plan assigning the entire Pacific theatre to – the by-now evicted from his base in the Philippines – Douglas MacArthur. Ernest King, the navy Chief, vehemently opposed this arrangement that would see his forces idling about the theatre. The Joint Chiefs, Marshall, King and Arnold, set about carving up the Pacific region into distinct theatres assigned to the three-stars who happened to be in the areas, regardless of service and with all military assets (land, sea and air) under their tactical command: MacArthur, Nimitz and Gormley/Halsey (Borneman 2012). Jointery (and not just 'Combined Operations') was born. For all this, the staff structures remained service-based. Nimitz's Naval staff prepared his plans while the Army War Department staff prepared MacArthur's (Allard, 1996).

The great leap forward, to seal the US as the progenitors of the Third Generation, was the National Security Act of 1947 by which – among the Department of Defense (DoD), the CIA, and the Joint Chiefs – the Joint Staff was brought into the world. 'G-numbers' finally became J-numbers.

2.4. 4th generation HQ – NATO and the DoD

The injection of the US staff structure, and then its extension, across NATO took place with Eisenhower's arrival as Supreme Allied Commander Europe (SACEUR) at Supreme Headquarters Allied Powers Europe (SHAPE) in 1950. This has led to the CJSS with which many are familiar: J1-Personnel, J2-Intelligence, J3-Operations, J4-Logistics, J5-Plans, J6-Signals/Communications, J7-Training, J8-Finance, and J9-Civil-Military Cooperation. This uniform structure now solved one of the interoperability issues of WWII related to recognition of peers and partners between various staffs.

This era must also be characterised by the attempts to enhance and speed up communication and information flow across now large numbers of diverse (in language, above all) forces across Western Europe and the Atlantic. This effort was driven by projects under the US DoD, the child of the 1947 reform. The role of technology was now to transcend the telephonic paradigm of switchboards and point-to-point linkages (Welchman 1982). Extending from the mid-60s with the advent of digital computer automated tasks, for example (extending developments discussed earlier) further removing the human element from sensor-to-shooter systems of now a variety Services such as coordinating air and naval gunfire, in spectrum allocation for increasingly sophisticated radio networks, moving into the 70s and 80s with the incorporation of digital data, and the 90s with the incorporation of web-based services – the field is replete with the graveyard of 'acronymned' systems: JTIDS, TBMCS, WWMCCS, and lately GCCS.

The Joint Tactical Information Distribution System (JTIDS) is a useful microcosm of this story. JTIDS sought to decentralise the flow of *tactical* information while building in security and jam-proofing. Its practical fulcrum would be the system of networked computers incorporating increasingly powerful and cheap microprocessors that could handle both digital and, though in small amounts, voice data. It may be regarded as the earliest formulation of a User Defined Operating Picture (UDOP), in that all the same data would be available to all users, but the receiver would select the relevant information. The fly-in-the-ointment that would slow this program for decades was the US inter-service rivalry over standardisation of data on which the architecture would operate (Allard 1996).

The relevance of the story of JTIDS is that it mirrors all the issues in building a technology for headquarters staff: respect for appropriate decentralisation, standardisation, automation of tasks at which human operators are least efficient, integration of sensors, visualisation of the environment for situation awareness and adaptation to new technology while the system is being built. The Worldwide Military C2 System (WWMCCS), built to drive national level strategic and operational staffs, was never more than a tying together of disparate sub-systems (Dick and Comerford 2005) which, nevertheless, proved critical in the success of the first Information Age War of Gulf War I. It was succeeded by the Global C2 System (GCCS), that integrates data processing and web-based services, but which also devolved into service-based versions (M, AF, and A) but now finally has reached its Joint (GGCS-J) implementation. The key output of GCCS is a display – effectively *the* COP - that may be accessed by staff in any headquarters – in an *Operations Room* - combining geospatial representations and imagery overlaid with partially-automated update of data as geometrical shapes, showing both own forces and threats. Arguably, the most recent development in this respect is Command Post Of the Future (CPOF), that builds on GCCS type platforms allowing for flexible visualisation of information (graphs, tables, maps), marking-up, annotation and both synchronous and asynchronous collaboration. Such displays are the culmination of the developments that began with the map in Napoleon's headquarters, through a dreadnought ship's plotting room and the CIC.

But through all this, technology has rolled on to the point where civilians have access in the palm of their hand to a tool that integrates data, provides static and dynamic text, numeric, and graphic displays, permits even up-to visual communications: the SmartPhone. At no point in this chain of sensing to display is a human manipulating data. And not only does this system give an unparalleled and accurate representation of the state now and in the past, but by accessing schedules and timetables as desired, and through recommendation aids, may enable anticipation into the future. In that respect, the SmartPhone takes the user across all three levels of Endsley's Situation Awareness model (Endsley 1995) of Perception, Comprehension and Projection.

2.5. 5th generation HQ – future

We may try already to anticipate what the future headquarters – a 5th generation HQ – may look like based on recent advances in C2 and developments in technology. Indeed, to the degree that C2 concepts of the last fifteen years are yet to be truly fulfilled in the sense of a completed Revolution in Military Affairs, we may ask whether the fourth generation headquarters remains a work-in-progress before considering the fifth, or should recent concepts be folded into the fifth generation, or, finally, is the failure to achieve the promise of such C2 concepts because of a lack of advance in technology?

Network centricity in both technological and human dimensions is well-known and is often expressed in the (US) Four Tenets of Network Centric Warfare (NCW): robust networking improves information sharing; information sharing and collaboration enhance shared situational awareness; shared situational awareness enables self-synchronisation; and these increase mission effectiveness. For a headquarters, where planning and control of execution of operations are the mission, these tenets have led to a number of characteristics for a networked headquarters (Alberts and Hayes 2007), above all enhancing collaboration and information sharing. These include planning activities that enhance informational position rather than commit large resources too early, formation of small-world network structured collaborative teams across diverse areas of expertise, and planning integrated – in time, and across staff – with execution. In information sharing, the expression is extending Smart Push to *Smart Pull* so that warfighters may access the information they need at will.

Some nine years after these, and similar ideas, how far have we progressed? In terms of overcoming the hierarchy of a typical J-staff to achieve networked (for example) planning teams little has changed. Our experience is that military staff, once posting into a functional area (or Branch), take considerable time to discover appropriate lateral linkages in other areas as they undertake formal processes such as operational planning. One might say they struggle to go from a hierarchy – or *Machine organisation* in Mintzberg's (1979) typology of organisations - to a process based organisation, or *Divisional form* in the Mintzberg scheme. The leap to genuine network centricity, with staff recognising genuine peers and collaborators across the headquarters, is often one taken reluctantly if at all. On the achievement of shared situation awareness, there is at least one scientific view that SA cannot, in general, be shared because it is fundamentally *distributed* across an entire cognitive system of human and technological agents (Stanton 2006). A further impediment to self-synchronisation is often poor articulation of Commander's Intent, either by accident (lack of skills) or design. In information sharing, the tendency is rife for subordinates being risk averse and therefore large scale 'carbon copying' in email traffic to 'cover one's back', and thereby contribute to an information deluge. Thus even information 'push' is not 'smart'. As for 'pull', some senior staff have explicitly commented to us: "I'm a busy person, I don't have time to pull information". Indeed, that is what junior staff are often employed for. Finally, humans are essentially tribal creatures – they are "contingent cooperators" with both strong cooperative dispositions and selfish "ancient primate dispositions" (Richerson et al. 2006) - and, as such, will always seek to define a boundary to a tribe and characterise someone outside it as 'the other'. Our experience here has been that where members from three military services are brought together into a Joint team, for example in J5 for planning, they will then regard another team, for example J4 logistics, as the "other" – and thereby create impediments to genuine collaboration. Another example is that members of one service may be brought into a Joint headquarters and, with little else having changed, be viewed by their home service as "other" – creating impediments to joint-single-service collaboration.

On the technological side, technology continues to advance within headquarters organisations as more web-based services are implemented. But, given the nature of IT procurement and control by central agencies in a Department or Ministry of Defence, and because 'networking a force' is a complex mixture of new procurements and upgrading existing platforms, such advances lag considerably behind the implementation of 'smart' technologies in start-up or small enterprises where the burden of legacy platforms is minimal. We have observed junior ranked operators that are skilled with a gamut of Smart devices in their private lives but tasked with mandraulic processing of data to feed a COP built on legacy IT in their work in a headquarters. Finally, there is a dimension to the technology that has its roots in diverging concepts for the organisation that change is seeking to bring about. Drawing upon Mintzberg's ideas, Lars Groth attempted in 1999 to forecast the types of new organisations that may become available with the advent of the technologies that have become identified with the Information Age. Two are of note (Groth 1999): the *Interactive Adhocracy*, a form that resembles the Edge Organisation of the NCW literature where technology enables peer-to-peer collaboration of unprecedented scale (beyond the usual size feasible for unmediated human teams), and the *Joystick Organisation* where an Executive or Commander is offered such detailed SA and control that operations may be singly controllable from the top. Quite different forms of technology are required to enable these two forms, yet many current defence IT projects around the world mix these technologies (Kalloniatis et al. 2011), thereby setting in tension Power to the Edge and Power to the Centre. CPOF is arguably such a system: the same means allowing disparate members of a team to collaborate enables a commander to micro-manage operations.

The impediments to change are then two-fold: human and technological. As discussed throughout section 2, from technological perspective, the last 4 generations of HQ have experienced two large scale technological revolutions that brought about profound societal changes – the industrial revolution and the information age revolution. However, archeological evidence suggests that such large scale technological/societal revolutions can only occur when key ingredients of technologies are all present at the same place and at the same time, each of which may have been 'deposited' at vastly different points in time to reach such a state of potential breakthrough. But even when every component of required technology is available, there is no guarantee that a so-called revolution will happen; in other words the right application of these technologies together is a necessary condition but not sufficient condition for such profound changes (Fletcher 2015). It has been widely speculated that advanced AI and robotic technologies, plus ever more pervasive networks and the availability of mega sized real time sensing data, e.g. the Internet of Things, will propel human beings to the next societal revolution. The issue is we do not know what constitutes a sufficient condition. Even for fulfilling the necessary condition, the question remains that what is the complete set of technologies that will enable this revolution or is there still a key piece to the puzzle missing. Nonetheless it is safe to speculate that these technologies will bring change in how human activities might be organised and envisage that a 5th generation HQ will be characterised by the proliferation of AI based autonomous agents both within HQs and in a battlespace over which they exercise C2.

However, can humans trust these technologies and overcome their reluctance to change C2 practice in order to embrace the opportunity? What are other characteristics of the 5th generation HQ in addition to technologies? To explore this we employ our second lens to examine the analogy to other 5th generation systems.

3. 5th generation HQ through an analogy lens

More so even than HQs, capability evolutions have been happening across all warfighting domains through history. Especially in air warfare, the latest capability hinges on 5th generation fighters. Even though there is no conclusive definition of a 5th generation fighter, it is a well-accepted naming convention to represent the most advanced fighters at the present time. The broad agreement around the world on the categorisation of jet fighters is:

- The first generation is the early subsonic jet fighter
- The second generation is characterised by the introduction of air-to-air radar and guided missiles
- Manoeuvrability and the introduction of multirole aircraft are what defines the third generation
- The fourth generation includes a massive leap in avionics, such as heads-up displays as well as aerodynamical design
- The current state-of-the-art fighters under production are considered to be fifth generation fighters.

The well recognised characteristics of a 5th generation fighter can be therefore summarised as: stealth, high manoeuvrability, advanced avionics, networked data fusion and multirole capability (De Briganti 2012). In the rest of this section, we will expand these characteristics one by one and define the corresponding desired characteristics for a 5th generation HQ.

Nose-to-tail low observable or stealth technologies are often touted as the first key characteristic of a 5th generation fighter. Stealth allows the fighter to approach its target destination to a much closer distance without being observed in order to produce shock and maximise its effect. For an operational HQ – being often located outside the immediate area of operations - physical stealth is not the most pressing concern. However with the cyber domain becoming increasingly critical to warfare and highly contested, the ability to manage the visibility of a HQ's cyber activities at will is going to provide a winning edge over a sophisticated adversary. By this we mean not only the requirement to guarantee the security of a HQ's freedom of operation in cyber space, but also to determine and reveal the appropriate cyber footprint according to operational needs. Hence the first desirable characteristic of a 5th generation HQ is *managed cyber visibility*.

High manoeuverability is another hallmark of a 5th generation fighter. This enhanced capability is enabled by controllability at slow speeds and high angles as well as the ability to cruise at supersonic speeds. The combination of superb manoeuverability and stealth makes it possible for a 5th generation fighter to defeat a numerically superior force. With ever growing pace and complexity of operations over which an operational HQ must exercise C2, there is a greater emphasis on C2 agility (STO NATO 2014). Contingency theory stipulates that organisations must be structured in such a way that it is fit for purpose, i.e. for any given contingency there is a corresponding organisational structure which is optimal for managing it (Mintzberg 1979). Hence in order to be able to provide C2 over vastly different operations in a fast changing environment, an HQ must be able to change and tailor its planning and response processes and organisational form rapidly to stay in the game and ahead of enemy's Observe, Orient, Decide and Action (OODA) loop. Here we are emphasising organisational agility, which encompasses 4 out of the 6 enablers of agility identified by STO NATO (2014), namely responsiveness, flexibility, adaptability and innovativeness (we will touch on the other 2 enablers, versatility and resilience, later) to achieve planning and response agility as well as superior decision making cycles. Thus the second desirable characteristic of a 5th generation HQ is *organisational agility.*

A 5th generation fighter possesses advanced avionics and its complexity is often expressed by the number of lines of code[2]. One aim of such advanced avionics is to generate 360-degree battlespace awareness for pilot, without the need to rotate the aircraft. It gives the pilot the ability to 'look' through the airframe by having multi-spectral sensors across all aspects. This in turn enhances the aircraft's ability to use its suite of weapons to engage and neutralise an adversary without them even being aware of the threat. As information systems within HQs get larger and more complex and the sensors in the battlespace become ubiquitous, networked, and more capable, data overload is of real concern. On the other hand with increased mission complexity and more blurred boundary between tactical and operational levels, time available to process this data and make decisions is further compressed. A 5th generation HQ will be required to move into the application of big data techniques (Symon and Tarapore 2015) and to employ decision support/aid systems including AI agents. These systems should be able to facilitate innovative and rapid decision making through automated fast analysis, synthesis and rich data visualisation in an easily tailorable COP or planning timeline. Thus the 3rd desirable characteristic of a 5th generation HQ is the effective use of *Advanced C2/Decision Systems.*

5th generation aircraft are organically designed to be networked, rather than have networking capability bolted in as an afterthought. This allows them to receive, share and store information to enhance the SA for the pilot as well as gathering information to perform its role as a collector and contributor to overall battlespace SA. Similarly, information sharing is key to multi-partnered operations, not only with own and coalition military force elements but also other government agencies and non-government entities which may be participating in complex operations. HQs that are intrinsically designed to be networked and to consider collating and fusing information from all relevant entities within an operation from planning stage through to execution phase are more likely to enable commanders to be effective decision makers, which in turn will lead to better mission outcomes. Thus the 4th characteristic of a 5th generation headquarters is *Networked information fusion across battlespace and partner entities.* Naturally, this feature is a prerequisite for the 3rd characteristic, above.

A 5th generation fighter is expected to be a complete multirole platform. Unlike the 4th generation fighters which can perform air-to-air, air-to-surface and reconnaissance missions separately, 5th generation fighters have swing-role capability, which is defined as "the ability to employ a multi-role aircraft for multiple purposes during the same mission"[3]. Operational HQs in Coalition nations have already faced for some time an expanding mission set, which ranges from Humanitarian

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[2] F-15A has 60 000 lines of software code, while the F-15E has 2.4 million.

[3] http://www.military-dictionary.org/DOD-Military-Terms/A/6/swing-role, https://www.eurofighter.com/the-aircraft

Assistance/Disaster Relief (HA/DR), counter terrorist, counter insurgency and nation building to high end warfighting. Sometimes several mission types can happen within a single operation (also known as the Three-Block-War since the late 1990s). As stated in the Australian 2016 Defence White Paper (DoD Australian Government 2016), the Australian Defence Force (ADF) is required not only to perform all its current roles, but also to expand its capability to shape and influence the strategic environment. This ability of C2 of operations over a whole spectrum of mission types and even managing multiple distinctly different activities from the spectrum of conflict simultaneously necessitates a 5th generation HQ to be versatile. Therefore the last desired analogous 5th generation characteristic is *Versatility*.

One last C2 agility enabler (STO NATO 2014), resilience, is not explicitly reflected in these characteristics. However it is integral in numerous places, for example in managed cyber visibility and advanced C2/decision systems; it is a given that these systems must be able to withstand attacks and recover graciously.

4. 5th generation HQ through an effect lens

Now let us examine a 5th generation HQ through the lens of 'what effects it should generate'. The landscape of modern military operations has shifted drastically to the extent that military victory can hardly be achieved in its own right anymore and its outcome becomes very intertwined with other dimensions, e.g. economic and diplomatic dimensions. This calls for what has recently been named the Comprehensive Approach. Williams (2011) provides a thorough account of the evolution of the Comprehensive Approach in NATO and reflects on its implementation in the first Helmand campaign in Afghanistan by the UK. To properly execute the Comprehensive Approach to achieve ultimate mission success, an operational HQ has a pivotal role in fusing kinetic, non-kinetic, and unconventional effects and integrating national power. However, recent operational experience has demonstrated that current HQs designed primarily for C2 combat missions, are not equipped to gather, process and making decisions based on other kinds of information required to fulfil this role (Davids et al. 2011). Hence the first effect a 5th generation HQ should generate is *to bring integrated national power to bear in areas of operation*.

As alluded in earlier sections, next generation platforms and capabilities will proliferate in the near future and the number of robots and synthetic autonomous agents are predicted to grow significantly to completely transform the composition of a military force. The mission spectrum is becoming increasingly wide and more complex. As long recognised in the Command and Control research community, tried and tested traditional C2 approaches may not be adequate anymore and experimental results have shown that information sharing policies and practices are not enough to mitigate risks posed by inappropriate C2 approaches (Alberts and Vassiliou 2015). Researching new C2 approaches which are commensurate with new mission challenges and new capabilities is the whole impetus of the current ICCRTS – C2 in a complex and connected battlespace. Hence the second effect a 5th generation HQ should generate is *to exercise C2 efficiently and effectively over 5th generation capabilities*. Because of the speed and scale of data of 5th generation capabilities, the HQ must itself be a 5th generation sociotechnical system.

5. Why do we need 5th generation HQs?

There are many drivers dictating the needs for a 5th generation HQ. We already mentioned that the emergence of 5th generation capabilities coupled with an ever more complex and connected battlespace requires newer C2 concepts and approaches, which in turn requires an organisational form – a HQ – to function as the brain of such a sociotechnical system. Correspondingly military HQs need to evolve to adapt to this role, hence a 5th generation HQ.

Robots are already being used widely in the civilian world to replace humans in dangerous, dirty and demeaning – and dull - roles as well as data intensive and fast decision making environments where human cognitive capacity is outstripped, e.g. high speed stock trading. It requires no stretch of imagination to envisage many staff functions in a HQ being performed by AI agents. The speed of AI technology advancement is astonishing. AlphaGo has recently demonstrated its overwhelming advantage over a human professional player at the most complicated board game – Go (Google DeepMind 2016). All forms of AI technologies are showing promise: cognitive computing, deep learning, deep visual reasoning, digital twinning, machine learning, neural networks, neuromorphic computing, recommendation engines, text exploitation, just to name a few. Every corner one turns, one encounters a new surprise in the AI field. A new HQ concept is urgently required to fully exploit these exciting advances and yet at the same time guard against potential pitfalls.

Developing military powers are not saddled by legacy IT and may be able to build organic AI based information and communication systems. Proliferation of and reduced cost of smartphones, smart-drones and the like mean that non-state actors can reduce the technology asymmetry in information, situation awareness and decision making arena. Regardless whether western established military forces wish to move to a 5th generation HQ or not, potential adversaries will move in that direction leaving no choice - if not proactively, western established militaries will have to play catch up.

From an Australian perspective, the ADF will conduct most of its operations with its allies and interoperability will always be an important factor to consider. Other members of Australia's alliance and coalition partners have already recognised the importance of changing HQ organisation and structure in response to new missions and new technologies. For example, Ezell et al (2000) reported a reengineering effort based on systems engineering methods to enhance the performance of US Joint HQs in informing, deciding and implementing decisions. The US DoD is actively seeking the Third Offset Strategy, with human-machine teaming or 'centaur' at its heart (Freedberg 2015). The promise is that leveraging the strengths of both humans and machines will create a new capability edge. To maintain Australia's interoperability with the US when they have successfully transformed their HQs would require the ADF to have centaur-filled HQs – 5th generation HQs.

Equally important, the recently published Australian Defence White Paper (DoD Australian Government 2016) articulated that, confronted with greater security uncertainty and complexity in the next two decades, Australia is determined to maintain its technological edge and capability superiority over potential adversaries. Decision superiority is a linchpin in the capability superiority sought. The performance of an operational level HQ underpins the decision superiority achievable by a force, so moving to a 5th generation HQ is not optional.

6. Principles of 5th generation HQs

We come now to the principles upon which 5th generation HQs should be designed bearing in mind the ‘what’ and the ‘why’ discussed above. There is nothing particularly novel about these principles except that, we argue, they must be organic to the HQs in their organisational form and their technological construction.

The first principle is that of Requisite Variety by Ross W. Ashby (1956), often expressed as follows:

> *If a system is to be stable, the number of states of its control mechanism must be greater than or equal to the number of states in the system being controlled*.

In this context, we refer to two systems: the controlling (the one seeking to remove perturbations) and the controlled (the one generating perturbations). Here the headquarters is the former, planning and controlling operations conducted in an environment that, through an active adversary or the forces of nature, is a source of instability. Refinements of Ashby’s principle enable more precise implications for headquarters organisation. The Conant-Ashby Good Regulator theorem, for example, implies that the controlling system must in a very real sense model the controlled system to be successful. Stafford Beer’s Viable System model seeks to frame the Principle for organisations in terms of sub-systems (1-5) that expand the time-horizon of activities from the here-and-now, information channels, structures and controls, and then future states and policy. In some respects this model may be aligned with Boyd’s OODA loop or Endsley’s SA levels, to which we come soon. Contingency Theory (Donaldson 2001; Mintzberg 1979) is another restatement of Ashby’s principle offering organisational and environmental variables which must be commensurate in order that an organisation is fit-for-purpose for its environment.

The importance for a 5th generation HQ is that, to have organisational agility and versatility, it must be able to easily change its structure to match the variety of contingencies or operations it must oversee. Its variety must be able to match the complexities of its allies and its adversaries, as well as technologies. Again, this has already been anticipated in notions of C2 Agility (Alberts 2011) except that we argue there are circumstances where even a hierarchy is fit-for-purpose. For this reason we have thus far left unspecified the organisational form of a 5th generation HQ: what should come after the CJSS? A 5th generation HQ must be able to deform from a default structure to a range of forms - Divisional, Adhocracy and others - as required, and return to a default structure. What that default structure should be remains unknown. At least at the scale of human teams of 10-20, there is a known asymmetry in the direction of such changes of structure for the maintenance of performance (Moon et al 2004; Jundt et al. 2005): Machine to Organic (or Adhocracy) rather than the reverse. Can AI technology overcome this or expand the size of the organisation over which such modifiable structures are achievable, for example by prompting the human staff in the functions and processes of the default mode? An aspect to this is the transformation of the role of the Chief of Staff in the HQ and their relationship to the Commander, seen in our historical survey. Can AI replace the Chief of Staff, regulating the rhythm of the HQ and guiding the activities of the Principal Staff Officers, however their functions may be labelled? Similar to this, but in the planning domain, can AI fulfill Mintzberg’s (1994) role of “left brain” (logic and analysis) functions in strategic planning – managing the inputs and outputs of fundamentally human “right brain” (intuition, synthesis and creativity) strategy formation activities, acting as catalysts for strategy, and controllers for the implementation of plans?

The second principle is that a 5th generation HQ must be designed based on a *tailorable* distribution of SA – consistent with the organisational form to which the HQ moves for the contingency - to drive an appropriate OODA. A 5th generation HQ will be a small scale complex sociotechnical system. Cognition, hence SA, is distributed amongst its agents. Every agent - be it human or synthetic autonomous agent - takes information out of working (human) memory, lodging it, enabling access to it, thus the overall SA resides within the system. The hybrid human-machine team that is the fabric of a 5th generation HQ must be carefully designed to guarantee that the distribution of SA is robust and flexible. Where the Operating Picture is appropriately Common, the AI may distribute SA accordingly and assist human staff to tailor the picture to their requirements; where, through rigorous application of sensitivity requirements, the picture must be compartmented, the AI correspondingly manages this restriction. This flexible distribution of SA enables a natural HQ OODA loop. However, such a loop is a collective effect – not necessarily guaranteed - of the dynamical interaction of many individual human and synthetic agent OODA loops (Kalloniatis 2016). Hence the design of the HQ and the AI systems within it should be such as to guarantee successful synchronisation within the HQ and, in the spirit of Boyd's intent, ahead of that of the adversary.

We have to embrace the second machine age (Brynjolfsson and McAfee 2014) and determine how AI may be cleverly teamed with humans in a HQ to help finally achieve a range of capabilities: agilely switching organisational forms, identifying potential collaborative partners dynamically, smart pull information automatically, completing backlogged tasks after crises collaboratively and quickly to return to routine, and project futures to devise more appropriate courses of action. A HQ staffed with *well-designed* hybrid human-machine teams will outperform one staffed only by humans or machines.

7. Summaries

Figure 1 summarises the thread of ideas in this paper diagrammatically. In this paper we proposed a 5th generation HQ concept and examined it using three lenses: literally - from a historical and technological perspective, analogy – as an analogue to 5th generation fighters, and effects – from the perspective of expected effects it should generate . We also explored potential drivers dictating the necessity to consider a 5th generation HQ concept seriously and articulate some underlying principles that underpin the arguments in this paper. We believe we have presented the case for a 5th generation HQ concept sufficiently to stimulate future research in addressing C2 organisational issues while incorporating synthetic autonomous agents, in a complex connected battlespace.

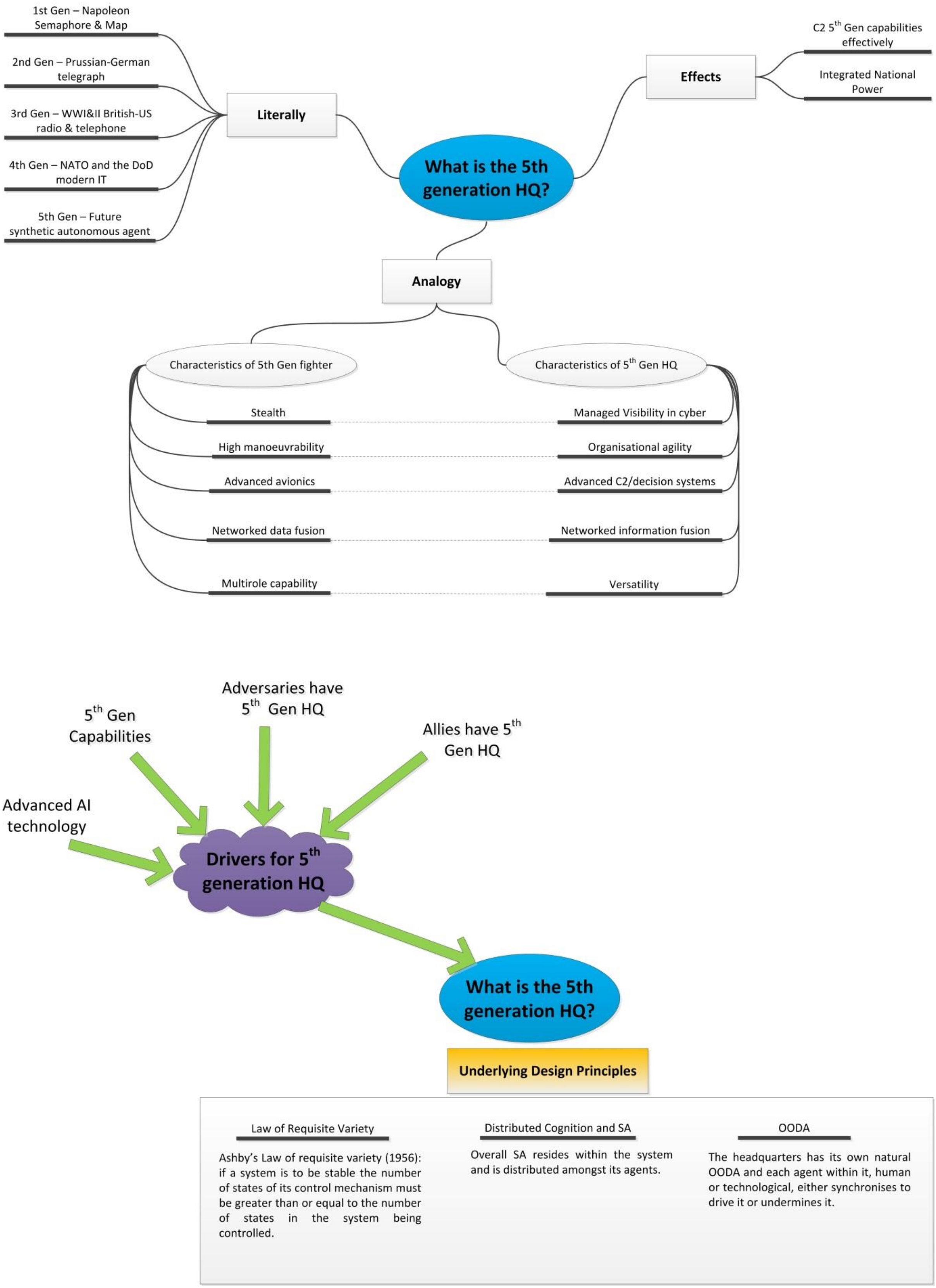

Figure 1. A diagrammatic summary of the concept of a 5th generation HQ

Acknowledgement

The 5th generation HQ concept was initiated by Australia's Chief of Joint Operations VADM David Johnston. The authors are in debt to VADM Johnston for allowing us to develop and elaborate on his ideas and have benefited significantly from stimulating discussions with him.

References

Alberts, D.S. and Hayes, R.E. (2007) 'Planning: Complex Endeavours', CCRP, US DoD

Alberts, D.S. (2011) 'The Agility Advantage', CCRP, US DoD

Alberts, D.S. and Vassiliou, M.S. (2015) 'The Quest for Key Information: Does C2 Approach Matter?', the 20th ICCRTS

Allard, K. (1996) 'Command and Control, and the Common Defense', Yale University Press

Ashby, W.R. (1956) 'An Introduction to Cybernetics', Chapman & Hall

Borneman, W.R. (2012) 'The Admirals', Back Bay, New York Boston London

Brynjolfsson, E. and McAfee, A. (2014) 'The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies', W. W. Norton & Company

Davids, C., Beeres, R. and Grant, T. (2011) 'Command and control in the Afghan desert: a field study at a NATO headquarters', *Int. J. Intelligent Defence Support Systems*, Vol. 4, No. 2, pp.111–127

De Briganti, G. (2012) , 'F-35 Reality Check Ten Years On -- Part 1: 'Fifth-Generation' and Other Myths', http://www.defense-aerospace.com/article-view/feature/135080/f_35-reality-check-10-years-on-%28part-1%29.html, published May 9, 2012, accessed April 2016

Dick, D., and Comerford, J.D. (2005), 'C2 Policy Evolution at the US Department of Defense', 10th ICCRTS

DoD Australian Government (2016), 2016 Defence White Paper, Commonwealth of Australia

Donaldson, L. (2001) The Contingency Theory of Organizations, Sage, Thousand Oaks

Durham, N.L. (2015) 'The Command and Control of the Grand Armee: Napoleon as organizational designer', Pickle Partners Publishing.

Endsley, M.R., (1995) 'Towards a theory of Situation Awareness in Dynamic Systems', Human Factors, 37, 32–64.

Ezell, B. C., McCarthy, D. J., Ratliff, W. L. Jr. and McGinnis, M.L. (2000), 'Joint Military Headquarters Redesign', Proceedings of IEEE International Conference on Systems, Man, and Cybernetics. Nashville, TN, USA, 8 October 2000, **1**, pp. 484-489

Fletcher, R. (2015), 'Complexity and cultural transitions: 100,000 BP to the present', Conference on Complexity, Criticality and Computation, C3-Autumn 2015, U. Sydney, 30 April 2015

Freedberg, S. J. Jr (2015), 'centaur Army: Bob Work, Robotics, & the Third Offset Strategy', http://breakingdefense.com/2015/11/centaur-army-bob-work-robotics-the-third-offset-strategy/, published November 2015, accessed April 2016

Friedman, N. (2008) 'Naval Firepower: Battleship guns and gunnery in the dreadnought era', Naval Institute Press

Galison, P. (2003) 'Einstein's Clocks, Poincare's Maps', Hodder and Stoughton, London

Goldrick, J. (2014) 'Learning to use the remote', Conference on early 20th Century Anglo-German naval arms race, Royal Navy Museum, Portsmouth, UK, 16-18 July, 2014

Goldrick, J. (2016) 'Meeting the challenges of the new: understanding operational developments in naval warfare in Northern European waters after the Battle of Jutland', Conference on the First World War at Sea, 1914-19, National Maritime Museum, Greenwich, UK, 3-4 June 2016

Google DeepMind (2016) 'AlphaGo', https://deepmind.com/alpha-go.html (accessed April 2016)

Gordon, A. (1996) 'The Rules of the Game: Jutland and British Naval Command', John Murray, UK

Hutchins, E. (1996) 'Cognition in the Wild', MIT Press, Cambridge, Mass

Jundt, D., *et al.* (2005), The impact of hybrid team structures on performance and adaptation: Beyond mechanistic and organic prototypes, 19th Annual Conference of the Society of Industrial and Organizational Psychology, Los Angeles, CA

Kalloniatis, A., Kohn, E., and Macleod, I.(2011) 'Matching teams to Contingencies in Military Command and Control Organisations', TTCP Technical Report DOC-HUM-6-2011, Work Analysis Methods and Applications: a selection of papers presented at the TTCP Defence Human Systems Symposium, Sydney, May 2010, Ed. Skinner, M. et al., pp.28-41

Kalloniatis, A. (2016) 'Testing AI watch-keepers in a mathematical model of networked OODA loops', 21st International Command and Control Research and Technology Symposium, Sep 2016, UK

Keegan, J. (2002) 'Intelligence in War', Vintage Books, USA

Mintzberg, H. (1979) 'The Structuring of Organisations', Prentice-Hall, New Jersey, 1979

Mintzberg, H. (1994) 'The fall and rise of strategic planning', Harvard Business Review 72(1): 107-114

Moon, H. et al. (2004), Asymmetric adaptability: Dynamic team structures as one-way streets, *Academy of Management Journal*, 47, pp681–695

Padfield, P. (2009) 'Maritime Dominion and the triumph of the free world', John Murray, UK

Richerson, P.J., Collins, D., Genet, R.M. (2006) 'Why managers need an evolutionary theory of organizations', Strategic Organization, 4 (2), 201-211

Stanton, N. et al. (2006) 'Distributed Situation Awareness in dynamics systems: theoretical development and application of an Ergonomics Methodology', Ergonomics, 49 (12-13), 1288-311

Symon, P.B., Tarapore, A. (2015) 'Defence intelligence analysis in the Age of Big Data', JFQ 79, 4th Quarter, 4-11

STO NATO (2014), 'SAS-085 Final Report on C2 Agility', http://dodccrp.org/sas-085/sas-085_report_final.pdf

Van Creveld, M. (1985) 'Command in War', Harvard University Press

Vassiliou, M.S., Alberts, D.S. and Agre, J.R. (2015) 'C2 Re-envisioned: The Future of the Enterprise', New York: CRC Press

Welchman, G. (1982) 'The Hut Six Story', Baldwin

Williams, M. (2011) 'Empire Lite Revisited: NATO, the Comprehensive Approach and State-building in Afghanistan', International Peacekeeping, 18:1, 64-78, DOI:10.1080/13533312.2011.527513

Zabecki, D.T. (2008a) 'The Chief of Staff Vol I: Napoleonic Wars to World War I', Naval Institute Press, Annapolis

Zabecki, D.T. (2008b) 'The Chief of Staff Vol II: World War II to Korea and Vietnam', Naval Institute Press, Annapolis