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Title: ISTAR and C2 – A Holistic View		
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This abstract is for a paper that is part of a set by Dstl and QinetiQ which discuss topics of current interest. Each paper stands on its own though common themes connect them.

ABSTRACT

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The common-sense application of communications and information technologies to C2 and ISTAR has had some notable successes, but no longer seems to be giving the desired benefits. Holism seems to provide an adequate theory for command and information systems, but is not currently well understood. *This paper introduces the idea that water can be used as a powerful metaphor for other holistic structures, such as C2 and ISTAR. Specifically, the relationship between their structure and emergent behaviours are key to an understanding of both water and holistic C2 and ISTAR, which are agile and yet cohesive and tend to preserve their combat capability ('volume').*

Although metaphors have to be treated with care, some examples are given of liquid ISTAR and liquid C2-ISTAR coupling. The liquid nature of water is due to the 'building block' nature of its structure. Exactly how this leads to water's emergent properties is not fully understood, but even here the metaphor may be helpful in understanding why the structure of C2 communities and the nature of their coupling and influence are so problematic. More positively, the metaphor suggests that more suitable 'building block' support by equipment is required for effective (liquid) situation awareness and sense-making, so that one quickly attend to new situations whilst maintaining necessary cohesion of perception and overall awareness or sense-making capability. The theory and practice of Holism helps suggest what this support might be. In particular, it is suggested that too rigid a demarcation between cognitive and physical domains constrains liquid behaviour and that at their boundary we need to be concerned about the propagation of influence and the actual nature and role of 'information'.

Introduction

The need

It is widely recognized that our current understanding of C2 and ISTAR is not up to current challenges. For example, the recent CCRP publication 'Understanding C2' says:

> **The world of Command and Control is in the midst of a paradigm shift**, a change in the way we think about the subject. … It is time to recognize that … there will be major discontinuities between the Command and Control concepts and practices being taught and practiced today and those of tomorrow. … A major discontinuity that will need to be addressed will be the definition of the words themselves.

> This is because **the way that these words have been defined** drastically limits the available solution space and **points us in the wrong direction**. (Alberts & Hayes 2006)

This recognizes that, although the common-sense application of communications and information technologies to C2 and ISTAR has had some notable successes, as we have attempted to move from small-scale systems to larger 'systems of systems[1]', we no longer seem to be doing so well. Our equipment shortcomings seem to correlate with, and may be caused by, some deep-rooted – systemic - problems (Hitchins 2005). As 'Understanding C2' suggests, paradigms and the meaning of words matter, and we need something to give the confused C2 domain 'shape'. Holism, as discussed in the appendix, would seem to provide the fundamental solution, but is notoriously inaccessible. We need an easier 'in'.

Liquids as metaphor

A metaphor takes a relatively concrete thing, such as water, and compares it to a more abstract thing, such as holistic C2, in the hope that it helps us the better to understand the latter. The validity of a metaphor depends on the correspondence being accepted, and on the metaphor leading to new insights. In both aspects it must rely on some existing body of understanding, as summarized in the section[2].

The idea of using liquids as a metaphor for C2 appeals because, as will be described more fully in the next section:

- Networks are an accepted model for C2 (Moffat 2003, Alberts & Hayes 2006). Fluids are networks with agility, so they can rapidly change shape. Liquids in addition are cohesive and are (in a sense to be made clearer below) sustainable.
- C2 is commonly thought about in terms of complexity and dynamics, with an understanding of emergence being key (Moffat 2003, Alberts & Hayes 2006). The same is true for water, with being liquid the key emergent property. Water is currently better understood than C2.
- It is recognized that large C2 systems are systems of systems, and that is a key to their understanding (Krygiel 1999, Hitchins 2005, Alberts & Hayes 2006). Similarly for water, which as systems of systems of atoms is currently better understood than C2 is.

Thus a liquid metaphor in some sense embraces the currently accepted metaphors (networks, systems of systems) while identifying desirable behaviours, including agility (fluidity) with cohesion.

Liquids also preserve their volume, and in this sense sustain themselves, unlike gases which tend to dissipate, or can be readily compressed. Thus liquids are like a military force, which typically seeks to sustain or restore its fighting capability through or after action. But what makes a liquid liquid? The main problem with water as a metaphor for C2 is that it is so little understood, but then if C2 is genuinely complex then so must our metaphor be. At least we know something.

Implications

The implications drawn out by the main body are seen generally in:

- the difference between cohesion and coherence
- the split between cognitive and physical 'dimensions'
- the difference between 'on the edge of chaos' and 'power to the edge'
- the nature of information management
- the implications of attritional vice manoeuvrist approaches.

My own work, though, has been more concerned with Intelligence and RSTA/STAR[3], and in their relationship with C2. Here, at least, we shall see the need to be more, and what is needed to facilitate it, particularly in:

- the nature of information 'as a whole'
- trade-offs in situational awareness between agility and cohesion
- managing sources 'as a whole'.

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[1] Systems of systems are systems that contain systems. For example, most military units can be viewed as systems composed of elements of other systems, such as logistics and artillery, and their computer and communications provision typically reflects this.

[2] Whilst remembering that: "The price of metaphor is eternal vigilance." (Rosenblueth & Wiener www.brainyquote.com).

[3] I.e., 'Reconnaissance', 'Surveillance', and 'Target Acquisition' in some order, according to your convention.

The main body seeks to tease some of the above issues out. At least if we can distinguish between what we really know and what we only suppose, we may be able to make progress despite our ignorance.

Background

Holism

Holism concerns evolutionary part-whole relationships, including those of military C2, polities and subsequently found in water. For example, a holist in considering a group of people 'as a whole' is considering not only the group, but the individuals as individuals and all their relationships to each other and the whole. In this sense it resembles some of the current network-based sociological theories. Holism is described further in the appendix. It has long been recognized that such part-whole relationships are important:

> … in war more than in any other subject we must begin by looking at the nature of the whole; for here more than elsewhere **the part and the whole must always be thought of together** (Clausewitz 1832).

'Understanding C2', e.g. as quoted in this paper, acknowledges this. Holism seeks to identify a particularly way, which arise out of British military practice and which is still largely reflected in it. Unfortunately, the main sources (e.g. Smuts 1926, Whitehead 1929, Keynes 1921) are notoriously obscure, and the actual influence on current C2 and ISTAR equipment practice is questionable. For example, Holism is often confused with 'top-down' wholism, the view that the parts should be subordinated to the whole. Thus while Holism may be technically correct, this may not – on its own – be a particularly useful insight, since we lack an accessible way of explaining what it is.

> One of the most of important of these Information Age skills will be **exploiting the power of metaphor** (JDCC 2004).

Extant metaphors

In this situation a good metaphor can be helpful. If one can agree on the metaphor in broad terms (e.g., 'network' or 'edge') then one can often collaborate on the details. The human central nervous system was used by UK doctrine as an effective metaphor, but it became undermined as computers began to be taken seriously as metaphors for human brains. Current sources of metaphors[4] include:

- Management Information Systems etc (Hitchins 2005)
- Networks (Moffat 2003)
- Complexity (Moffat 2003)
- Systems of Systems (Krygiel 1999)
- Games / Dramas (Howard 1999)
- Edge (Alberts & Hayes 2003).

These do not seem to be working well enough (Alberts & Hayes 2006). It has even been suggested that system thinkers don't need a new metaphor, whereas inexperienced engineers will never 'get it'[5] (Hitchins 2005). Clausewitz is still well respected 'on war' generally. He warns of the dangers of an inappropriate metaphor, not linked to sound theory. He used a metaphor involving electric charges with poor conductor between (Clausewitz 1832), but this doesn't seem to have been particularly effective and now seems largely disregarded. However, it is suggestive of the liquid metaphor, below.

Liquids

From a reading of those war-fighting experiences that informed the development of Holism, it is notable that:

- In the Great War, locally organized troops (gases) couldn't muster enough concentration, while lines of troops (solids) broke as they came against focussed resistance in strongholds.

[4] These all have bodies of work that are simpler and more concrete than real C2, and used as metaphors.
[5] 'It' being the nature of the part-whole relationship.

- Liquid forces can form solid-like waves but then can flow over and around strongholds, washing away resistance, and then regroup in more solid forms.

In this sense, being liquid seems to describe that type of 'systems' behaviour that the military advocates of Holism seemed to be striving for. So what makes a liquid a liquid?

> Enlightenment comes from an understanding that water molecules form an infinite hydrogen-bonded **network** with localized and structured clustering. The **middling strength** of the connecting hydrogen bonds seems ideally suited to life processes, being **easily formed but not too difficult to break** (Chapman 2006).

If we call the structures in water 'communities', then the current open questions on the structure of water include:

- How do you **distinguish the members** of a "[community]" from adjacent [entities] that are not in that [community]?
- Since individual [communities] are continually breaking and re-forming on a [relatively short] time scale, do [communities] have any meaningful existence over longer periods of time? In other words, [communities] are transient, whereas "structure" implies a [C2] arrangement that is more enduring. **Can we then legitimately use the term "[community]" in describing the structure of [a force]?**
- The possible locations of neighboring [units] around a given [unit] are limited by energetic and geometric considerations, thus giving rise to a certain amount of "structure" within any [part of a force]. It is not clear, however, to what extent these structures interact as the size of the [force being considered] is enlarged. And as mentioned above, **to what extent are these structures maintained [over time]**?"

This resonates with open socio-technic questions in C2: how do we facilitate and manage agile yet cohesive C2 communities? This exposes the limitations of the application of engineering to complex systems and perhaps illuminate why we struggle to provide definitions of key terms (Hitchins 2005, Alberts & Hayes 2006).

John Desmond Bernal worked on liquid crystals, following the ideas of (Whitehead 1929) as an alternative to conventional functional modelling. He generalized his findings thus (1967):

> Life is a partial, continuous, progressive, multiform and **conditionally interactive self-realization** of the potentialities of (atomic electron states).

This is a holistic view, which he applied as science adviser to General Montgomery for a period that included the planning for the Normandy invasion[6]. This showed continuity with the earlier work of Clausewitz and the later work of Boyd.

Boyd

US Col. John Boyd is a well-respected practitioner who has had a big impact on military thinking and practice concerning decision-making and C2 following the Vietnam War. He often most often associated with decision-making by pilots and a simplified 'OODA' loop[7] (Lind 1985), but his work is much broader than this. For example, he observed of C2:

> Note how orientation shapes observation, shapes decision, shapes action, and in turn is shaped by the feedback ... Also note how the entire 'loop' (not just orientation) is an ongoing many-sided **implicit cross-referencing process** of projection, empathy, correlation, and rejection (Boyd 1996).

This description of C2 is reminiscent of Bernal's description of water (above), and clearly holistic[8] (Smuts 1926 & 1931, Bohr 1958). This suggests to me that the liquid metaphor is reasonable. Boyd's ideas, like Holism, are of great import yet have not had their full impact. Maybe the liquid metaphor will help.

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[6] Bernal (1929) wrote "Rationalism … never succeeded … because it was itself too arbitrary, too tainted with distorted primitive wishes ever to be brought into correspondence with reality." A notable feature of military decisions, such as the Normandy planning, is its lack of classical rationality (Marsay 2000). This is because, as was found in the Great War, the Plato's classical 'axiom of comparability' (Keynes 1921) simply isn't true of sufficiently complex systems. This was why Morgan (1950) found the academic planning theory of the day of so little relevance. (Unfortunately, the lessons learnt from the Great War, primarily based on Smuts' work, were still being worked on.)

[7] Observe, Orient, Decide, Act. Similar to See, Think, Act, Reflect.

[8] Boyd based much of his more technical work on Bohr, who had worked for Smuts and whose work is clearly holistic.

Boyd also had a notion of "getting inside the opponent's 'decision-loop'", by which he meant "Changing the situation more rapidly than the other side can comprehend." This can be by physical or cognitive means - be quick or be cunning. Unfortunately most of those quoting Boyd have focussed on the former to the detriment of the latter (Lind 1985)[9]. We shall see later how the liquid metaphor can help us to understand this aspect of C2.

Understanding C2

The CCRP's recent 'Understanding C2' (q.v.) does not use the term liquid, and uses the term fluid just once:

> In today's operations however, characterized by a compression, if not elimination, of meaningful distinctions between strategic, operational, and tactical processes and rapidly shrinking windows of opportunities for effective action, a **more fluid approach** that allows for simultaneous planning and execution makes more sense. … The degree to which planning and execution are separate and sequential versus integrated and simultaneous **will directly affect C2 agility** and thus force agility in the context of a mission.

The work notes that this:

> C2 Approach consists of:
> (1) the way decision rights are allocated,
> (2) the patterns of interaction that are enabled, and
> (3) the distribution of information across the elements of the force.
>
> While the C2 Approach may change over time (for example, as the force moves from crisis management to combat to stabilization operations) or differ across function (logistics and fires may employ very different approaches), choices made on these three fundamental dimensions are profound decisions with far-reaching implications for the overall C2 process.

Thus it has the same dynamic mereological (part-whole) concern of Holism that, as we shall see, the liquid analogy is intended to capture. Here we use the term liquid to cover Bernal's concern for cohesion. The importance of this will depend on the context.

The context for C2

'Understanding C2' characterizes the C2 problem space in terms of the rate of change in the situation and our understanding of it. The latter is broken into two aspects. The first is the familiarity, which affects our ability to ask the appropriate questions and make use of the answers. The second is our strength of information position, which is our ability to answer the questions. Thus Intelligence and RSTA / STAR have a very close relationship with C2 as a whole. We shall see some of the implications for C2 later.

> **An operation of war can't be thought-out like building a bridge**: certainty is not demanded, and genius, improvisation, and energy of mind must have their parts. (W.S. Churchill[10])

Today, the UK's Joint High-Level Operational Concept (HLOC) shows the following components of agility.

[9] More recently, it has been noted that orientation is often treated as simply processing (Thackray 2003). This distorts Boyd's work out of all recognition.
[10] In (Sandys & Littman 2003).

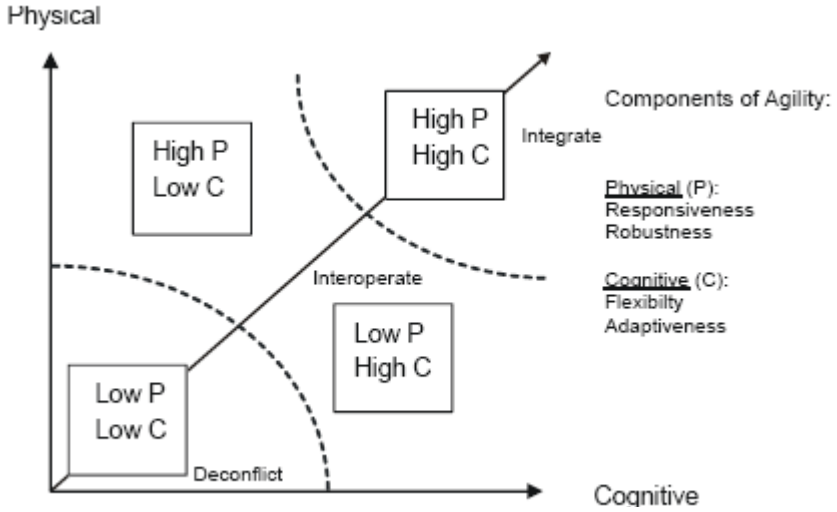

Figure 1: *UK Joint High-Level Operating Concept, components of agility*.

Here 'Integrate' means to "Combine or be combined with to form a whole". Quite clearly, then, HLOC is calling for agility with cohesion, or – in terms of our metaphor – being liquid (JDCC 2004). Thus we see that high agility is required when there is a high temporal and cognitive stress. This is complements the 'Understanding C2' view[11].

Liquid C2

From the discussion above, it is perhaps already clear that liquids provide a useful metaphor for C2. Here we seek to refine the metaphor, set it in context, and then apply it, to yield some useful insights.

Scope of the metaphor

It seems helpful to consider two aspects of being liquid. The first is that it is dynamic, the second that it can maintain cohesion and capability ('volume') despite complexity. Thus, while gas can fill arbitrary shapes, it then has no useful dynamic (i.e., it stabilizes), and no cohesion. Ice can move quickly (with the help of water acting as a lubricant), but only over a sufficiently flat surface – unless it shatters. Water combines movement with the ability to maintain cohesion despite environmental complexity[12]. Can we apply this to military C2, or systems engineering? Will we reach cohesive conclusions?

In real systems of interest, direction is an issue, and liquids in so far as we have considered them are not directed in the same sense that we typically wish our forces to be. Hence we have to admit that our metaphor only covers maintaining cohesion, not the direction or channelling of the cohered whole. Nor does it include anything like the classical 'observer'. But, as consideration of the previous metaphors shows, even a limited metaphor may be useful. Or you could always imagine watching someone undermining a building, say, with water.

Related concepts

There are a broad range of management concepts that are relevant to C2. They each tend to have variations, spanning concerns about tempo and efficiency to concerns about being clever and effective. Thus they match to the dichotomies of Boyd, 'Jt. HLOC and 'Understanding C2'. In table 1, below, I review some concepts that I have had to consider in my own work on the C2 of intelligence[13].

Concepts	*Efficiency focus*	*Effectiveness focus*
Concern	Doing it right (correctness)	Doing the right thing (appropriateness)

[11] This type of theory is known as a contingency theory – that the appropriate organisation is contingent on the challenge (Vroom & Jago 1988). Understanding C2 and Jt HLOC are identifying key factors in the challenge. Coalition working may introduce other challenges.

[12] Later, we shall see that it is enabled to cope with environmental complexity by its own complexity (Ashby 1960).

[13] As we shall see, the efficiency focus corresponds to the recommendations of the NATO C2 model (SAS 2006).

Concepts	*Efficiency focus*	*Effectiveness focus*
Context, values, constraints	As given, simple, predictable	Problematic, complex, uncertain
Data	Measures, information	Indicators, Evidence
Cognitive style	Situation awareness	Sense-making
Effects, ends / ways /means	Routine	Conditional, uncertain
Values in time and 'space'	Coherent	Contrasting
Progress indicators	Useful	Not possible
Solution	Objective (Unique, verifiable)	Subjective (Multiple, Judgement)
Solution approach	Determination. calculation	Decision, Choice
Aim	Definite values / behaviours	Constrained values / behaviours
Ideal Behaviours	Order, Stability	Variability, Variation
Part-whole relationship	Constructivist	Emergent
Interaction	De-confliction / Co-ordination	Collaboration
Organisation	Integration, coherence	Federation, Cohesion
Management approach	Systematic, constraining	Systemic, self-restraining
Management style	Managerialist[14], delegation	Specialist, professional, discretion
Role of Humans	Operators	Users
Work style[15]	**Mechanistic, engineered**	**Exploratory**

Table 1*: Management concerns, related to efficiency and effectiveness*

It seems to me that the efficiency focussed practices are less liquid, and the effectiveness focussed practices are more liquid. But more than that, the liquid metaphor suggests that the real challenge lies in 'veering and hauling' between the two. The liquid metaphor supplies some substance to this insight, and being backed-up by modern science – post Smuts' Holism (Smuts 1931, Capra 1982) – may provide a robust way forward.

> While technical thought or skill enables a man to deal with the same circumstances that he has met with before, **scientific thought enables him to deal with different circumstances** that he has never met with before. Clifford, quoted in (Fuller 1926).

In terms of my current research interests, the liquid metaphor has clear implications for:

- Coherence versus cohesion
- 'Sharing' 'Situation awareness'
- Edgeness
- C2 and ISTAR models.

Coherence versus cohesion

Cohesion means sticking together. Coherence, in the sense used here, implies not only sticking together, but being consistent, and in particular in having some consistent relationships, as do coherent light and pure regular crystals, such as diamonds[16]. Following the Dark Ages and prior to Holism one seemed to have a stark choice between individualism and wholism: that is between bottom-up anarchy and top-down 'Prussian militarism'. In effect, coherence seemed necessary to cohesion. For example, to quote Clausewitz (1832):

> … war is an indivisible whole, the **parts of which have no value** except in their relation to this whole.

Thus, under attack one had no choice but to be wholistic and to seek coherence. This was epitomized by an ideal regiment largely consisting of cloned soldiers with identical kit performing drilled activities[17]. But

[14] Managerialists view management as the most important aspect of an organisation (Parker 2002). This may be a failing if the organisation depends on its technical professionals (e.g., commanders) more than its managers. (This is an insight born out of the military experience of the Second World War (Drucker 1955, Marcuse 1964)).

[15] This last line is my attempt at a summary.

[16] ``... it is no doubt important to attend to the eternally beautiful and true. But it is more important not to be eaten." (Fodor 1985)

[17] This was perhaps on aspiration of Frederick the Great.

today we aspire to Holism's 'third way' of 'organized chaos'[18], recognising that over-management limits achievement. As with a liquid, *we seek agility with cohesion*. While the world would be a simpler place if the troops and their activities were more coherent, so that we had a relatively simple system of systems (as in a modern aircraft) (Krygiel 1999), we must recognize the reality of a more complex complexus of systems of systems, as is water. If you make a liquid more coherent, it becomes a solid (e.g., ice). In solids, as in steel, greater coherence (purity and homogeneity) can introduce 'fault lines' that reduce resilience and hence cohesion. A classical homogenous system of systems (singular) is coherent but not agile. A heterogeneous complexus of systems of systems that is integrated in the holistic sense is both agile and cohesive. One could no more have effective militaristic C2 than have life build out of conventionally structured components[19].

Thinking about liquids may help us to understand the difference between coherence and cohesion – and that it matters[20]. This gets to the heart of notions of 'command and control'. For example, perhaps contrary to classically educated common sense, a coherent system of systems will necessarily lack the agility of more holistic systems of systems[21].

Situation awareness

The mainstream C2 view of perception is that it is more or less direct, giving a rough correspondence with notionally objective reality, and leads to awareness, thus:

> Recent work of the SAS-050 NATO Working Group has stressed that **data, when placed in context such that it reduces uncertainty, becomes information, while information becomes awareness when it passes from information systems into the cognitive domain** (a human brain). Humans, as individuals, actually hold awareness of situational information and combine it with their prior knowledge and mental models … to generate situation understanding, which includes some perceptions of the cause and effect relationships at work and their temporal dynamics. (Alberts & Hayes 2006)

This classical model is very appealing, but is difficult to relate to the perception of the structure of water, especially bearing in mind the open questions above (under 'liquids'). It is also difficult to relate the scientific view of Bacon (1620):

> The Idols of the Tribe have their foundation in human nature itself, and in the tribe or race of men. For it is a false assertion that the sense of man is the measure of things. On the contrary, **all perceptions, as well of the sense as of the mind, are according to the measure of the individual and not according to the measure of the universe**. And the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolors the nature of things by mingling its own nature with it.[22]

As in water (above), there may not even be any comprehensible classical real structures to be aware of (Keynes 1921). This is particularly so in times of transformation (Whitehead 1929). Thus, in conflict:

> … the **perception of the mind is judgment** … and consequently art; and … even the **perception by the senses as well**. (Clausewitz 1832)

> **Without speculation there is no good and original observation**. (Charles Darwin[23])

This aspect of 'awareness' is dealt with in more detail in the next two sections, on information and ISTAR. Meanwhile, next we consider to what extent awareness, whatever it is, should be shared.

Sharing situational awareness

> **If everyone is thinking alike, then somebody isn't thinking**. (George S. Patton)[24]

Coherence and synchronisation in action are generally desirable, and coherence and synchronisation in 'situational awareness' will tend to be necessary and sufficient for coherence and synchronisation in action.

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[18] Organized Chaos is characteristically British, but anathema to stereotypical engineers and managers (Hitchins 2005).

[19] Thus, one could not envisage life as constructed from atoms and molecules without having some holistic structures such as water (Smuts 1931).

[20] Smuts (1926) thought that humans had a 'sixth sense' for coherence, which could be a weakness where the thing being observed was not actually coherent. Francis Bacon (1602) called this tendency an 'idol of the tribe'.

[21] E.g.., crystals are coherent. Plastics are not.

[22] The First Idol of the Tribe is that "human understanding is of its own nature prone to suppose the existence of more order and regularity in the world than it finds."

[23] Letter to A.R. Wallace, 22nd Dec. 1857.

[24] www.brainyquote.com

Some go further, and claim or assume that coherent shared[25] situation awareness[26] facilitates efficient and effective action (Alberts et al 1999, JDCC 2004).

On the other hand, a liquid approach would be to allow autonomous missions and only cohere them where and to the extent that the missions need to be cohered.

> The battlespace could be configured for efficient information sharing by **identifying communities of interest** within which **information flows are matched to reflect different needs** … (JDCC 2004).

Thus one seeks a liquid cohesion rather than a solid coherence. This allows both decision quality and speed, by trading-off coherence. But fluidity has implications for the technological networks and requires the communities to be managed (commanded[27]), and in that sense goes against both the conventional desire for orderliness and the newer concept of 'edgeness'.

It would be foolish to design systems on the basis of a metaphor alone, but perhaps the metaphor should cause us to review the work of Ashby and Boyd, for example. Ashby (1960) purports to show that C2 can only be effective in complex situations by harnessing the complexity of its components – which enforcing coherent situational awareness does not do. Boyd's law (q.v.) (applying Bohr's law) has it that one has to trade-off one's ability to regulate externalities with one's regulation of internalities[28]. Either way, we need to consider what we mean by 'shared situation awareness'.

Recently, 'Understanding C2' says of *complexity:*

> braided or entwined together, inseparable, or interdependent. … **cannot be deconstructed into … manageable or predictable pieces**.

It also quotes Murray Gell-Man to the effect that:

> **effective complexity can be high only in a region intermediate between total order and complete disorder**.

This also seems to cast doubt on the wisdom of seeking coherent situational awareness, except where (to use 'Understanding C2's term) the situation is familiar, possibly more familiar than it would be reasonable to assume for future conflict.

Edgeness

The above discussion leads to the notion that where a situation is complex and dynamic, our C2 has to be complex and adaptive, and hence liquid. In this sense, we need 'organized chaos' or 'on the edge of chaos' (Moffat 2003). Thus in complex situations, attempts to be more organized, systematic or 'disciplined' are generally counter-productive. Good commanders aren't necessarily those who can create order, but those who see too much order as sign of potential brittleness, can shape disorder to their own ends and are prepared to create more disorder where appropriate.

'Power to the Edge' (Alberts & Hayes 2003) focuses on decisions being made at organisational extremes. This is not solid and conventional, nor overly organized, systematic or 'disciplined'. But according to Gell-Mann (above), neither is it particularly complex. Liquids are neither centralized solids nor totally decentralized gases, and thus offer a 'third way' (albeit a difficult one). This is compatible with Holism, which emphasizes the need for an appropriate balance between the parts and the whole, between the edge and the centre. Thus a coherent system of systems has components that are not just parts of the whole system, but have a 'life' of their own (Hitchins 2005). (Collective systems of systems are even more

[25] A share is 'a portion that a person receives from or gives to a common amount'. To share is to 'use or benefit from jointly' or to 'have in common'. It thus implies that there is a single thing (awareness) that is shared, whereas a more liquid approach would be to assume that each person's separate awareness are somehow inter-related, as in the awareness of car drivers. Unfortunately, it is not always clear to me in what sense the term is used in some recent C2 writing, which I must admit to taking literally, without any clear understanding.

[26] This is a complex subject (Banbury & Tremblay 2004). While Holism has much light to shed on the whole field, here we focus on the aspect of sharing.

[27] Holistically, not necessarily wholistically (centralized). For example, in convection water forms into structures of appropriate sizes in order to transport heat, and so the movement of heat becomes managed. We might wish to seed, shape or otherwise facilitate this, without necessarily having firm control. The details of convection are not well understood, but – for example – heating engineers seem to cope. Similarly, commanders cope, and we should seek a metaphor that supports them without bringing in misleading detail.

[28] Van Creveld makes a similar observation, arguing that 'a certain stability and homogeneity in organizational structure is vital' to improve the quality of normal communication, leading to a loss in agility. (van Creveld 1985, p273).

complex[29].) Thus while 'Power to the edge' may give us a sense of direction (away from centralized), Holism could provide a guide to a balanced goal, drawing on the liquid metaphor. Power to the liquid?

C2 and ISTAR models

Ideally, one would have a single model incorporating C2 and ISTAR, and everything of relevance, which would address the needs of the various stakeholders (e.g. users, maintainers, developers and procurers) and from which sub-models could be extracted and tailored to meet specific needs[30]. But if we think of a drink from a consumer's viewpoint, it is very different from the chemist's view, that "water molecules form an infinite … network …". Perhaps we could make do with a cohesive set of models, or a 'model of models'. These would not be entirely coherent in the logical sense. Instead (turning the words of Jt. HLOC to a different purpose) we might:

> be configured for **efficient information sharing by identifying communities** of interest within which **information flows are matched to reflect different needs** … .

Thus there are real gaps to be bridged between the users' 'C2ISTAR business models', the systems of systems architect's 'C2ISTAR business model' and the system engineers' 'C2ISTAR business models'. We confuse them at our peril.

Cognitive versus physical split

> **We are constantly confronted with the opposition** between matter and spirit, between the temporal and the eternal, **between the phenomenal and the real**. Holism shows these opposites as reconciled and harmonised in the whole. (Smuts 1927)

> **The intricate connections of mind and body must exceed our imagination**, as from our point of view we are peculiarly prevented from observing them. (Bernal 1929)

In Britain, at least, the socio-technic approach to systems used to be de-jure, but a common factor in most current approaches to C2 is to a have a clear split between the human sciences and systems engineering. This is clearly reductionist, rather than holistic. Fuller (1926) describes cognition thus:

> Whilst the interplay between ideas is imagination, and whilst **imagination is ceaselessly shuffling ideas** to and fro and weaving them into all manner of designs, according to the object which at the moment in control of the mind, **reason is simultaneously selecting** these designs which, when fitted together, like the pieces of a puzzle, will make a complete picture of our intention.[31]

This resonates with descriptions of liquids. But if we have a liquid cognition on top of a liquid mechanism we have two liquids, not one. Is this what we want? For example, if we have a collection of humans who have dynamic coupling both to each other and to their machines, which are also dynamically coupled together, then we can expect little clusters of relatively tight co-influence[32] to emerge (as in water). But how are such influences to be "matched to reflect different needs" as called for by Jt HLOC? An alternative would be to consider communities of people with equipment, and to manage them as a whole. The findings on situational awareness provide an example of this.

The Nature of Information

Here we make some general observation about the nature of information. They are developed in more detail in the next section, on ISTAR. This present section is necessarily difficult because, as we shall see:

> the way that these words [information, awareness, effects etc] have been defined drastically limits the available solution space and points us in the wrong direction. (Alberts & Hayes, 2006)

[29] A system has (or arguably, 'is') a single top-level regulatory regime. A collective of systems may have interactions, but has no overall regulatory mechanism (as in many polities or ecologies). A collective of systems of systems is collective of systems in which the component systems are themselves systems of systems. Thus, for example, systems of systems are open, whereas the top-level system of systems is closed.

[30] As in the recent NATO C2 Model (SAS 2006). This derives all of its views from a single reference model, thus ensuring their consistency. This seems to achieve its classical consistency by only considering the classical aspects of C2 (Appendix).

[31] Quote is (Fuller 1926, p215). Fuller is currently respected (Kiszely 2005).

[32] In this paper the term 'influence' may refer to anything that has an effect, not just subtle or psychological effects.

Information as description

Information is clearly key to C2. But what is it? 'Understanding C2', for example, seems to treat information as fact-like, with degraded quality, which includes completeness, accuracy and consistency[33]. As in the NATO reference model above[34], there seems to be a reductionist split between the physical, the informatic and the cognitive. Is this helpful? Is this all that C2 should use?

> **True genius resides in the capacity for evaluation of uncertain, hazardous, and conflicting information**. (Winston S. Churchill[35])

That is, 'genius' relies on the realisation that, contrary to the view of many current C2 theorisers and developers (SAS 2006), military information is often a not fact-like description, and in treating it accordingly. Is ISTAR, perhaps, a behind green-baize doors process that manipulates the given information (source reports) into the desired form ('facts') in some mysterious way, and then serves it up as fact-like intelligence? Or do we think that ISTAR should be constrained to serve-up realistic descriptions, leaving commanders to rely on some other support for dealing with other kinds of data? It would seem more liquid to accept that fact-like information, even of degraded quality, may only be an ideal, and that we should to attempt to deal intelligence as it really is, not covering over its inadequacies. We might ask of any theory: it is rich enough to cope with self-regulation in water[36]?

> **Make everything as simple as possible, but not simpler**. (Albert Einstein)

This issue is now confronted in respect to accuracy, consistency, effects, meaning, logical models, evidence[37], equivocality and context.

Accuracy and consistency

We normally seek accuracy and consistency in our information. But what do these terms mean[38]? In a coherent system the influences are clearly information-like, and may be said to have accuracy and consistency to the extent that it accords with some idealized average value. But generally there may be no ideal or average (Keynes 1921), and – as with water - the effect (or meaning) of the influence depends on the system's current structure[39]. Thus we can only think of the influence as information if there is a stable structure. But in water there isn't. There is no information in the sense that we normally think of it, and no sense of objective 'correctness' or accuracy. Moreover, as Clausewitz (1832) says, in conflict there is often 'uncertainty about the proper scale to use', so that even a technically accurate result can be misleading.

We have already argued that cohesion is often more important than coherence, so it should be no surprise if the entities of interest are often not coherent or consistent. That is, the thing that makes them cohesive is not a classical 'rule'.

Effects

> Earlier theorists aimed to equip the conduct of war with principles, rules, or even systems, and thus considered only factors that could be mathematically calculated (e.g., numerical superiority; supply; the base; interior lines). All these attempts are objectionable, however, because they aim at fixed values. **In war everything is uncertain and variable, intertwined with psychological forces and effects, and the product of a continuous interaction of opposites**. (Clausewitz 1832)

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[33] Van Creveld does the same, suggesting that the role of ISTAR is simply to provide enough relevant information (van Creveld 1985, p266).

[34] '*Direct sensing* takes place when humans experience an object or event in the physical domain with one of their senses … and the sensing registers directly in the cognitive domain' (SAS 2006).

[35] www.brainyquote.com. Also the Einstein quote.

[36] The structures in water 'as a whole' are self-regulating, agile and cohesive, and rely on influence propagating through the structure. But these influences are not like classical descriptions: compare the Background section with (Keynes 1921, Whitehead 1929).

[37] The recent NATO reference model only considers evidence about the model, not within C2 (SAS 2006), but we shall follow Keynes, Turing and Good in supposing the proper handling of evidence to be important.

[38] Degree to which information quality matches what is needed. Extent to which information is consistent with prior information and consistent across sources (SAS 2006).

[39] Here 'structure' is used in the sense of the liquids sub-section of the background section.

Classical effects propagate within stable contexts and can be described as mediated by classical ('linear') information[40]. But in water we see effects propagating where there is no information in the classical sense. Instead, there is a continual (holistic) process of transformation, a continual process of creative evolution. This reflects the nature of effects in conflict, as described by Clausewitz (1832), but in a very basic way.

These holistic processes and the influences on them need to be understood if similarly complex situations are to be appreciated and shaped[41]. Situations of interest will be this complex where they are dynamic, adaptive and self-sustaining, or at least, not sustained by us. That is, where they are agile with cohesion, i.e. liquid.

Meaning

> One has the vague feeling that **information and meaning may [be like] … conjugate variables in quantum theory**, they being subject to some joint restriction that condemns a person to the sacrifice of one as he insist on having much of the other. (Shannon & Weaver 1963)

In information theory, the thing that has effects but which is not classical information is termed meaning, as in the quote. The situation is similar to the case of quantum physics, referred to by Shannon and Boyd. There are information paradoxes for interactions that lack a fixed 'field' (Capra 1982). This observation doesn't really help us to understand what is happening, any more than we understand the structure of water. But at least we can locate the issues. For example, 'Understanding C2' splits 'situation understanding' into 'familiarity' and 'information position' and represents them as different dimensions. This could be taken as suggesting that they are independent, and that one gets benefits by just improving one of them. On the other hand, if 'familiarity' is something like meaning then the liquid metaphor links us to Keynes, Whitehead, Shannon & Weaver, Bohr and Boyd, for example. Thus it suggests that far from having orthogonal dimensions, an attempt to improve one factor could be detrimental to the other. Now, most equipment programmes have tended to focus on the information position, whereas the 'meaning' aspect of the situation is often of more concern to commanders, so it may be that current acquisition is handicapping commanders, for example in their appreciation of influence, effects and potential effects[42].

Completeness

We generally suppose that the more quality, the better. But is completeness always desirable?

> On the road from the City of Skepticism, I had to pass through the Valley of Ambiguity. (Adam Smith[43])

> We should as far as possible withstand the temptation to pour this plastic experience into the moulds of our hard and narrow preconceived notions, and **even at the risk of failing to explain all that we experience we should be modest and loyal in the handling of that experience**. (Smuts 1926)

There are two problems with using an assessment to cover over ambiguity:

- the need to maintain the assessments in the light of new reports
- the typical need to ensure consistency.

These are a form of inertia that inhibit agility and hence being liquid. Thus if the intelligence has a gap, it is more holistic simply to acknowledge the gap.

Logical models

Douglas Hofstadter popularized the view that mathematical logic – which underpins Holism (Smuts 1926) - was important (or even central) to any viable theory of mind (Hofstadter1979)[44]. In the 1980s his work was very much required reading for UK military C2 in Malvern, but has since become unfashionable[45].

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[40] Van Creveld gives an account of the ineffective or possibly counter-effective use of systems analysis in Vietnam, which is difficult to distinguish from some more recent approaches said to be 'effects based' (van Creveld 1985). The NATO model has only simple, linear, effects (SAS 2006).

[41] See, for example, Smut's accounts of operations or the work on effects that he sponsored (Keynes 1921).

[42] The NATO reference model only refers to meaning in terms of a seemingly fixed semantics, whereas to Commanders like Smuts and leaders like Churchill, it is the locus of the fight. Dialectics, not semantics!

[43] www.brainyquote.com

[44] Hofstadter's work is 'in the spirit of Lewis Carroll'. Carroll had two parallel careers. As a mathematics don he wrote the most popular textbook on classical logic, which as Carroll he then rubbished, pre-figuring much of modern logic. This is in direct contrast with more classical approaches (SAS 2006).

Whilst we do not have an agreed logical model of C2, any more than we have a normative model of water, and some take the view[46] that a logical model would be 'a bad thing', liquids are logical[47], and they do have agility with cohesion. So if (as some mathematical logicians would claim[48]) it is not possible to have a logical model for C2 in which familiarity and information position behave like independent dimensions; perhaps we should take note. This is important as much of the UK's current investment is going into improving the information position, whereas most of the problems seem to lie with meaning, which the use of technology can readily exacerbate. Some commentators seem to believe that this is an unavoidable effect of technology (Agar & Hughes 1999). This raises the question of whether or not information technology can be used to support information in the broader sense. It probably can, but only if we appreciate the difference between efficiency information and effectiveness information, as in the table above.

Evidence

> **Take nothing on its looks; take everything on evidence**. There's no better rule. (Charles Dickens, Great Expectations)[49]

The limitations of the fact-like notion of information were found in the Great War (Keynes 1921)[50], and alternative approaches were developed and applied in the Second World War (Good 1995). Briefly, one makes hypotheses about the situation that (at least in principle) entail predictions about what may happen in various circumstances. One then perform experiments or just observes, assessing the evidence against the hypotheses and developing those that do best while weeding out the rest (Fuller 1926, Good 1950, Marsay 2002).

Equivocality

> **Equivocality exists when a commander can map multiple mental models onto the … information** … . … in the future … it is likely that more information will create more equivocality. This may lead to …'decision paralysis'. … future commanders need … to deal with equivocality, in a similar way that current commanders have learned to deal [with] ambiguity (JDCC 2004).

Such equivocality[51] is needed when commanders are seeking to transform (Whitehead 1929) situations in a liquid way. It is clearly incompatible with the notion of fact-like descriptive intelligence. If we view equivocality as part of the commander's mission, then mission command is incompatible with coherent equivocality, and hence with coherent situation awareness. One cannot share awareness, only data. Moreover, it may be that the decisions of equivocating commanders cannot always be retrospectively rationalized against fact-like information[52]. If we expect commanders to be able to construct a conventional fact-like 'common picture' to justify their decisions in terms of supposedly objective facts, then we have to accept that this need to give a constrained account may constrain their action. Alternatively, we may be able transcend the picture-decision view of C2, and find better ways of trading off effectiveness and accountability. This will have obvious impact on ISTAR.

The liquid cognition envisaged by Fuller and HLOC implies that the 'information' cannot have been pre-mapped into fact-like form, but has to be held as evidence, where it naturally supports a liquid meaning and interpretation.

Context

The discussion above may be assisted by noting that information is 'data in context'. In solids the structure provides the context for interactions. In gases it is the bulk averages that provide the contexts.

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[45] For example, in the CCRP corpus Hofstadter's work is rarely mentioned, and then only marginally. Actually, I don't find Hofstadter quite reliable, except as a source of ideas and sources.
[46] They may be confusing logic with classical logic and reductionism.
[47] In the holistic sense (Whitehead 1929).
[48] For example, in Whitehead (1929).
[49] http://en.wikiquote.org/wiki/Charles_Dickens. Compare (Fodor 1983).
[50] As described in the appendix. Also in (George 1936).
[51] The new NATO reference model includes equivocality as a situation characteristic, but does not integrate it into the model as a whole, leaving us to wonder what is intended (SAS 2006).
[52] The general point about decision-making is made by (Keynes 1921) and Keynes' other works on Versailles and economics, by Lloyd George's support for Keynes, and Smuts' works and exploits, as described in the appendix.

Water, as we have seen[53], has no structure in the conventional sense, and hence has no conventional context. For example 'the mood of the meeting' is something that can be assessed although it cannot be objective. Such assessments are done by particular people in particular circumstances for particular purposes. Thus where one has an assessment, one needs to attend not only to the result, but also the circumstances.

Discussion

Our own work on ISTAR[54] has approached the issues somewhat differently to 'Understanding C2', but ended up at a similar position. However in our 'landscape', familiarity and information position are not different dimensions. Instead we have a single dimension, going from full understanding, through being in a well understood general situation, but with no detailed information on the current 'state', to having no understanding at all. This is not an ideal representation either. It suggests that if you are struggling over meaning then efficiency information has no value except in so far as it helps to clarify meaning. This is perhaps not strictly true, but for our purposes it seems more nearly true, allowing us to use the landscape more effectively.

The UK Joint HLOC distinguishes between cognitive and physical components of agility. Meaning and familiarity are clearly cognitive concerns. Information position is relative to a familiar context and hence liable to systemising and perhaps even being mechanized (Whitehead 1929). Thus it seems reasonable to treat it as physical, even if the current technology includes human brains. As above, the liquid metaphor suggests that one can't be agile in both cognitive and physical dimensions simultaneously. But the Joint HLOC figure 1 (above) only concerns capability, so that while a commander will need all of the components in their quiver, they may not be able to use all of them simultaneously. Hence there is no contradiction. What we seek to avoid is developing a capability to support those components of agility that we understand that inadvertently inhibits the components that we (as technologists) do not understand. The liquid metaphor puts us on our guard, and gives us some clues. In particular, the liquid metaphor suggest that Keynes, Whitehead, Smuts, Bohr and Boyd (for example) are relevant to military C2, and so challenges the commonplace concepts of control, accountability, measures of effectives and of 'effects base' approaches, perhaps more radically than does 'Understanding C2'. As technologists, we may have something to learn from military best practice, such as mission command and the manoeuvrist approach, and from past informatic best practice, such as at Bletchley Park[55]?

No metaphor is perfect. One failing of the liquid metaphor is that water is only liquid over a narrow range of temperatures, and so we might think that we would rarely be faced with a liquid situation. We can counter this with a current military appreciation, that conflict is complex. (Albeit it would be less so if we were truly dominant[56].) Or, we can draw on the theory developed from the Great War experience (e.g., Smuts). Briefly, being liquid is a 'force multiplier', so non-liquid adversaries tend to get beaten, and moreover, conflicts between 'solid' forces tend to be of limited duration, as the sides cannot adapt. Thus long-running conflicts are likely to involve complex situations, and call for us to be more liquid.

Liquid ISTAR

Intelligence is not information

> **Many intelligence reports in war are contradictory; even more are false, and most are uncertain**. (Clausewitz 1832)

As we have seen, typical C2 information is thought of as fact-like, but of variable quality. Much of what RSTA/ STAR (Surveillance, Target Acquisition and Reconnaissance) provides can be thought of as observation, and hence as a form of C2-information. Difficulties arise with deception, which doesn't simply degrade the information, but makes it of a different type – disinformation. More broadly, Intelligence involves assessments that are different in kind from fact-like C2 information. In this sense, we can consider reports to be 'evidence'. They are information-like if the source is reliable, in which case the 'credibility' (or 'likelihood') can represent their quality. But otherwise our view of the reports should be equivocal, and the

[53] In the 'liquids' sub-section of the 'backgrounds' section.
[54] Command & Intelligence Systems Division of QinetiQ, for the UK MOD's ISTAR Research Programme.
[55] The conference organisers have arranged a visit.
[56] Superiority and dominance used to be an aspiration (e.g. (Alberts et al 1999)), but are not mentioned in recent works on C2 (SAS 2006, Alberts & Hayes 2006).

quality of the equivocality is as much to do with the commander as anything inherent in the report, and hence cannot be considered a quality of the report, but must reflect the commander's appreciation of the situation 'as a whole'[57] [58].

Role of ISTAR

In the above, we have mostly looked at C2, and sought to identify the impact in ISTAR. Unfortunately:

> The key to understanding the roles of and the relationships among battlespace entities is to **focus on processes that turn raw data into information, and information into knowledge**. (Alberts et al 1999)

Thus C2 and ISTAR are deeply entangled, to create a whole that can only be considered holistically. It is perhaps unfortunate, then, that there is so little funded research in the UK that seeks to address C4ISTAR as a whole. But maybe a good metaphor will help us make progress despite the reductionist research approach.

Sources need to be managed to gain evidence

One needs more information to fill gaps in one's knowledge or to remedy quality, to yield a given overall coverage and quality. Thus more evidence is needed partly to obtain sufficient weight. But it is also needed to cope with equivocation. In the first place, evidence can narrow down the range of equivocation. But, perhaps less obviously, evidence can also be needed to increase the range of equivocation. This is because modelling needs something to work with, and for lack of evidence will tend to be satisfied with an appealing simplification[59]. Thus one always needs evidence to prove the situation assessment. This is largely driven by imagination and paranoia ("worst-case analysis"), to ensure that one is considering a broad enough range of models. That is, it is driven by cognition but supported by equipment.

Evidence processing

It is clear from the above that intelligence is neither data nor conventional information, and needs to be handled accordingly. This will be different from conventional data or intelligence fusion, as it needs to support equivocality. The necessary underpinning is provided by the theory of 'weights of evidence', but this is not yet adequately developed. (That is, we do not have a sound general way of ascribing meaning to an assertion that 'the evidence supports such and such'.) However, practically, we can see how to reason using evidence in at least some cases of military interest[60], and it may be that in future we can achieve sufficient 'intelligence superiority' to avoid the more confusing cases.

The following example was developed for an MOD Research Programme study into Battlefield Picture Compilation for a conventional situation (Marsay 2002). For the actual study all activities and reports were pre-scripted, including the sensor deployments, tasking and reports. The variable was in the analysis of reports. In the base case the usual Intelligence Battlefield Preparation (IPB) was performed, to generate adversary courses of action (COAs) against various possible Axes of Advance (AA). Sensor deployments and tasks were developed. A single 'best guess' fact-like picture was then maintained from the emulated reports, used as information. This was found to be vulnerable to realistic counter-intelligence activity (mainly tactical deception).

The alternative approach uses weights of evidence, as at Bletchley Park but simplified (Marsay 2002). The main benefit sought was in the analysis, in avoiding deception. The IPB stage is broadly similar in this relatively familiar case, but can be more principled if required (for example, to deal with unfamiliar situations). The COAs were the desired hypotheses. The AAs were indicator hypotheses, and there were various technical hypotheses linking these together, and with source reports. Initially these were that the adversary followed its normal 'Fantasy Land' practice. Typically, the aim in deploying and tasking sensors would be to use the sensors so that one got a similar amount of information (expected weight of evidence

[57] ICCRTS delegates have an opportunity to visit Bletchley Park, where an understanding of these issues made a difference (Good 1995). It seems to me that they were astonishingly agile while maintaining adequate cohesion.

[58] A more prosaic link to liquids is provided by the close relationships through Turing and Keynes to Russell, Whitehead and Smuts, so that the understanding of the nature of water reflected the same advances in general logical, mathematical and scientific understanding as was reflected as Bletchley Park (Marsay 2002).

[59] Exceptionally, some commanders will get concerned if the situation appears too straightforward, or too like that which they had prepared for. They expect the unexpected, and are suspicious if they don't get it.

[60] For example, as used at Bletchley Park (Good 1995).

(Good 1950)) for all COAs. A simple traffic-light scheme was then used, with green for a good fit, red for a bad fit (tending to rule out the hypothesis) and amber in-between.

Initially the adversary generated a lot of activity, hoping to bury the reports of important activity amongst distracting reports ('information overload'). This gave us an amber indication and then a red indication against all hypotheses, as the analyst had not anticipated it[61]. The lack of a green indicator against any hypothesis suggested that the analyst should look for new hypotheses. Throughout the scenario the analyst went back to the IPB analysis and updated it where appropriate, thus performing an iterative IPB. He looked for simple hypotheses first, and then increasingly looked for more detailed (and cunning) hypotheses. Thus he considered new COAs using previously identified AAs, then on new AAs, then at novel unit formations, then at new vehicle types. Thus the lack of a good fit prompted the analyst to revisit the IPB in a structured way, until he had credible hypotheses (green). These were then monitored as more reports came in. In some cases he had alternative credible hypotheses that we wished to distinguish between. In this case the ISTAR staff would in practice wish to re-deploy or re-task our sources, but the nature of the emulation precluded this[62]. Even so, we found that we had early indications (from the traffic lights) that the initial expectation was unreliable, and the possibility of the actual deception plan was recognized in good time, thus avoiding the trap, and allowing the commander to equivocate. In this scenario, even if the commander had waited for an unequivocal 'picture', the actual activity was confirmed in adequate time for a tactical response. This was because, compared with the conventional approach, the evidence was considered in more meaningful chunks, and so the newer evidence, suggesting the deception, was not diluted by being mixed in with the old (confusing) evidence. Thus the emulations showed the value of using weights of evidence in the face of complexity, and that this approach could be implemented in a relatively straightforward fashion[63]. However, the ISTAR 'picture' showed traffic lights against the hypotheses (e.g. COAs) being considered, rather than a fact-like picture[64].

With our way of working, in making assessments, a lack of any green lights will have been due to some recent reports, but may also depend on some previous reports. This dependency comes about because reports not only fit or do not fit hypotheses, they tend to refine them. If a recent report does not fit a hypothesis it may be because a previous report forced us to refine the hypothesis. This general observation is illustrated by the link between COAs and AAs. For example, in reports may seem to rule out a COA, but only because previous reports had wrongly ruled out an AA. By looking at the weights of evidence and at the changes to the hypotheses, the analyst could identify sets of clashing reports which between them 'caused' the poor fit. These were reported internally for assessment, and in reality would have been considered for reporting to the commander or selected staff, in addition to their formally stated requirements. That is, we envisage an implicit IR of 'tell me anything that does not fit my assumptions'.

Sources should be managed as whole

Given a set of ISTAR tasks, if one managed resources separately for each mission, the reports for different missions might not be synchronized. Thinking about information in the sense of Shannon, the amount of pan-mission information is maximized when the reports are synchronized. Hence there can be a trade-off between satisfying the individual missions and providing maximum overall information. The solution proposed here is that any pan-mission requirements should be explicitly stated and prioritized[65]. Thus optimising the pan-mission information (the 'common picture') is not necessarily a priority.

Conclusion

The theme of this year's International Command and Control Research and Technology Symposium is "Coalition Command and Control in a Networked Era." This theme recognizes the increasingly networked world in which we live and in which military and civil-military missions are conducted. But what type of network? Taking materials as metaphors, networks can range from solid to gaseous. Traditionally the ideal

[61] For the purposes of the experiment the IPB was minimal, and minimally inspired.
[62] Although for some sources we could ask for more detail on what had been previously reported.
[63] Complications arise in setting thresholds for the colours if the sensor coverage is not uniform. These currently seem inevitable, and have yet to be addressed in detail.
[64] This did not use a formal tool, but simply adapted current manual military practice using a COTS presentation tool.
[65] It is envisaged that each requirement should be explicitly linked to missions, tasks and sub-tasks, so that prioritization is agile (JDCC 2004).

has been for a solid network supporting a solid force, rather than a gaseous one. A solid network is coherent but not agile. A gaseous network would be agile but not coherent. The current aspiration is for something that is both agile and cohesive, despite challenging threats. This challenges our conceptual carpet-bag.

Being liquid combines agility with cohesion. But if we take water as our metaphor, it has some surprising implications. For example, whereas for both solids and gases the nature of information, structure and effects are understood, for liquids such as water they are hardly glimpsed. Understanding fluids and understanding C2 are both about understanding the nature of the propagation of influence, which we do not. Thus, for example, the concepts of control, effectiveness and accountability become problematic. The appropriate response to complex situations is to adopt a more fluid C2 structure, as advocated by mission command and the manoeuvrist approach.

Of particular relevance to ISTAR and its interface to C2 is the notion of information. The term derives from the Latin *informare*, meaning 'to give shape to, fashion, describe'. Thus we may think of shaping information and describing information. In fluid situations there may be no 'objective reality' to describe, and hence no true describing information. Thus, ISTAR cannot provide a 'picture', but becomes a participant with the commander in shaping the situation. For example, if the adversary is fluid, in the sense that many players have discretion to affect the situation in ways that are not systematically subordinated to some cohering entity, there may be no precise coherent 'adversary intent' to be divined. There may be no describing information – only meaning. Fortunately, we have a worked example (at Bletchley Park) of how evidence may be used independently of context to support command. Whilst this approach has traditionally only been used at the strategic levels and above, we have seen how it may be applied at the army tactical level to counter deception.

The holistic or 'liquid' approach would seem to have wider applicability, wherever one needs an alternative to absolute or attritional war. Comments are welcome, particularly as concerns coalitions.

Appendix: Related work

Holism

Holism concerns part-whole relationships, including those in military forces, polities and subsequently found in water. Whereas the classical view is that the whole is merely the sum of its parts (bottom-up) and the wholistic view is that the parts must be subordinated to the whole (top-down), the Holistic view is a 'Third Way' that seeks an accommodation between parts and wholes[66]. For example, sheep and grass within an ecosystem co-evolved: the sheep to chew shorter grass, the grass to survive closer cropping. Similarly, whereas human biology must have predated human consciousness, language and society, human biology is affected by consciousness, consciousness by language, and language by society. Thus in evolved systems one cannot explain the whole (ecosystem, society) in terms of the parts (grass, people) or the parts in terms of the whole. Instead one looks for explanations in terms of the relationships between the parts and the wholes. This relationship may be stable (as in some isolated or managed ecosystems) or it may not (as in society).

As Clausewitz (1832), noted, Holism was needed to avoid the pitfalls caused by the spurious precision of the classical theories:

> … **all technical and scientific expressions which belong to a [classical] system, lose their propriety**, if they ever had any, **as soon as they are** distorted, and **used as general axioms**, or as small crystal talismans … .

Also, the classical notions are simply inappropriate:

> **How little the categories of [classical] arts and sciences are applicable to such an activity [war] strikes us at once**; and we can understand, at the same time, how that constant seeking and striving after laws like those which may be developed out of the dead, material world, could not but lead to constant errors. …
>
> But what can be gained for practical life by such obscure, partly false, confused, arbitrary conceptions? So little is gained, that **theory** on account of them **has always been a true antithesis of practice**, and frequently a subject of ridicule to those whose soldierly qualities in the field are above question.

[66] Fascism is an example of a 'Third Way', but Smuts, Churchill etc advocated a third way with a better 'spirit'.

The term Holism originated from Smuts 1926, building on the post-classical mathematical logic of (Russell & Whitehead 1913, Keynes 1921 and Whitehead 1929). While these works were popular and led to modern science (Smuts 1931), they are also notoriously obscure. Attempts to explain the theory that have been popular with some C2 practitioners include Koestler (Koestler & Smythies 1969), Hofstadter (1979) and Capra (1982)[67]. The ideas have been commended by, for example, Checkland & Holwell (1998).

Wholistic integration is where the parts are fully subordinated to the whole, as is achieved when some central entity has all of the authority, except that which it explicitly delegates. Holistic integration is where a balance is achieved between the interests of the individual parts and the needs of the whole. The difference is obviously significant for the human parts of a force, but has less obvious relevance to the equipment part. However, if we accept that C2 with ISTAR is sufficiently complex, then according to Holism there can be no single classical logical theory that spans it all, just as there can be no single classical logical theory that spans other complex domains, such as Physics, Chemistry and Biology.

The Holistic view was developed by J.C. Smuts based on his wide political and military experience. Smuts had been at Cambridge at the same time as Russell and Keynes (both under Whitehead), had become a leader against global capitalism, had advocated a manoeuvrist strategy in the Boer War[68], and then led a commando raid using Kant (1787) as a guide to defeating the more classically trained British Generals. In the Great War, after leading Empire forces in East Africa, Smuts was chair of the war priorities committee, often chaired the War Cabinet, and became known as 'the Handyman of Europe'. He later sat on the Second World War Cabinet, and helped found both the League of Nations and the United Nations. His Great War slogan was 'Right is Might', and he continually advocated the view – supported by Lloyd George and Churchill, and some British Generals – that right thinking was a 'force multiplier'. He later coined the term Holism in connection with his theory of evolution and emergence (Smuts 1926) (Smuts 1927). Smut's book was intended as a popular work, with work by Whitehead[69] (1929) and Keynes[70] (1921) providing technical support. Smuts' work became the basis for 'modern science'[71], but unfortunately all these works are notoriously obscure, but I take the work of Smuts, Keynes and Whitehead to be cohesive.

According to Whitehead (1929), a given model of reality is typically only reasonably coherent with reality, in the sense of classical logic, to a limited extent. It may be limited in current scope, in time, in detail and in level of 'abstraction'. Keynes made use of this, to the extent that 'Keynesian economics' was completely different for Britain and America. This reminds us of Clausewitz (1832):

> … each period has had its own peculiar forms of war, its own restrictive conditions, and its own prejudices. **Each period would, therefore, also keep its own theory of war**, even if every where, in early times, as well as in later, the task had been undertaken of working out a theory on philosophical principles. The events in each age must, therefore, be judged of in connection with the peculiarities of the time, and only he who, less through an anxious study of minute details than through an accurate glance at the whole, can transfer himself into each particular age, is fit to understand and appreciate its generals.

The reason is, as in water, that coherence would need some mechanism to maintain it, but the only available mechanisms are physical and hence relative, not absolute. Hence where agility is demanded (i.e., responding to irregular stimuli) only cohesion is possible. More generally, there is never a 'given context' that applies unconditionally. If a structure presupposes a given context then the structure, like a solid, is only conditionally strong. It has a weakness that may be exploited, by violating the assumption. Thus concepts of probability, measurement, information, value and of cause and effect all have limits, and are dependent on circumstances[72]. Models should be like mosaics, with each tile being itself a mosaic, and with mosaics forming tiles of larger mosaics. In this sense it is fractal, and resembles the structure of living things.

To this logical view, Smuts adds the view that the individual circumstances typically correspond to regulatory regimes, as in life (and water), and that transformations correspond to changes in regulation.

[67] Surprisingly, they do not make any explicit reference to Smuts or Whitehead.
[68] Wishing to avoid sieges.
[69] Smuts regarded his work (Smuts 1926) as a popular version of Whitehead's (1929). In fact, both became very popular, and have been frequently reprinted since.
[70] After the Great War Armistice Lloyd George asked Smuts to make sure that some of the key lessons identified were published, resulting in Keynes' work relating to effects (Keynes 1921).
[71] (Smuts 1931, Capra 1982).
[72] Whitehead uses the term nexūs, but here it is expedient to describe them as 'individual contexts', using 'context' to describe all the relevant nexūs.

Moreover, the regulatory regimes at one level are the entities at the next level[73]. Next, in order to thrive, a structure must normally adapt and be subject to some sort of evolutionary mechanism (e.g., learning). This implies that if a regulatory system is not used, it will tend to atrophy. Smuts also noted that regulation often only has partial or vague data available to it, and it was this uncertainty that was propagated, not classical 'information'.

Holism may be largely seen as extending the work of Clausewitz. The main difference is that whereas Clausewitz (1832) considered only two types of war (absolute and limited), Smuts introduced his 'Third Way', learnt from the Africans, and applied it to all complex endeavours.

Fuller (q.v.) claimed not to have read much science since 1912[74], so it may seem fanciful to read his 'Science of War' as an application of 'modern' science, which wasn't 'blessed' until 1929 (Smuts 1931). But Basil Liddell-Hart helped Fuller revise his manuscript[75], and provided social links to Russell and Lloyd George, and hence to the wider 'circle of ideas' including Whitehead's student Keynes[76] and Smuts. Hence I take his (and many other British generals) thoughts to be largely cohesive, albeit possibly in a different spirit. For example, the reader may recognize the following sentiment. It is not holistic, and may not be appropriate to complex situations:

> Let us devise so accurate a system, and let us present it to [the simple soldier] in so simple a form, that without thinking, **without perhaps knowing what we intend, he with his hands will accomplish what our brains have devised**.

More positively, Fuller calls for organizational fluidity with cohesion:

> …**practically every doctrine** established during peace-time **has proved itself obsolescent** immediately it is put to the test in war; the reason being that **these doctrines have been built on rules of strategical and tactical procedure dependent on the success or failure of fixed organisation**… .

We should be sure that our equipments for C2 and ISTAR do not constrain the organisation too much. In particular, we need to enable commanders to equivocate wherever and whenever they need to. Finally, Fuller notes:

> A purely defensive (secure) war means that the object is to return to the status quo before the war began; consequently that the war has lost its meaning, for **to wage war and return to the status quo is but to squander human energy**.

This has obvious implications for the development of doctrine, which currently, as it seeks to become more scientific, seems to be relying on ideas which assume some unchanging context rather than seeking a genuine transformation in the sense of Whitehead. (E.g., consider the 'effects based' literature (Storr 2005).)

Boyd's kinds of conflict

Boyd identifies three kinds of conflict:

- Attrition Warfare.
- Maneuver Conflict.
- Moral Conflict.

Of attrition, he observes

- Firepower, as a destructive force, is king.
- Protection … is used to weaken or dilute the effects of enemy firepower.
- Mobility is used to bring firepower to bear and to avoid enemy firepower.
- Measures of success are (now) "body count" and targets destroyed.
- Seize and hold terrain objectives replaces Napoleon's dictum: destroy enemy army.

Of maneuver, he observes:

- Ambiguity, deception, novelty, mobility, and violence (or threat thereof) are used to generate surprise and shock.

[73] E.g. in water sub-atomic particles form particles which bond together to form dynamic networks with fleeting structures and structures of structures, all going to make water.

[74] P17.

[75] P15.

[76] Russell had also been a student of Whitehead. Later Wittgenstein and Turing were students of Russell, and Keynes supported Wittgenstein while he was in a prisoner of war camp. Between them, they seem to have lived out Fuller's account at a social level.

- Fire and movement are used in combination … to tie-up, divert or drain-away adversary attention and strength in order to expose as well as menace and exploit vulnerabilities or weaknesses elsewhere.
- Indications of success tend to be qualitative and related to the widespread onset of confusion and disorder, frequent envelopments, high prisoner counts, or any other phenomena that suggests inability to adapt to change[77].

> Battles are won by slaughter and maneuver. The greater the general, **the more he contributes in maneuver, the less he demands in slaughter**. (W.S. Churchill[78])

Attrition seeks to change the context simply by wearing away some particular aspect until the system collapses through lack of some critical factor (e.g., ammunition, lives, morale). The use of attrition is thus compatible with the use of the most accessible and familiar intellectual tools. The manoeuvrist approach, on the other hand, calls for the use of more robust concepts, such as those Boyd advocates. In particular, the nature of accountability is different in the two cases, and only in attrition can one have familiar 'measures of effect'.

In terms of our complexity landscape, attrition warfare is associated with a concern for efficiency, grinding faster than the enemy. Manoeuvre is concerned with effectiveness. The aim of manoeuvre seems to be to change the situation to one that is more favourable in terms of the complexity landscape, for example shaping the situation to reduce its complexity. The manoeuvrist approach is more holistic[79].

Boyd actually treats moral conflict as different from manoeuvrist warfare, but from a Holistic view they seem much the same, and so I combine them here[80]. Thus it seems that in an attritional operation being liquid may have some tactical significance, as in waves washing against the shore, but in the manoeuvrist approach one needs to add being liquid in direction, to yield agility, with cohesion and direction. Or maybe the moral aspect is concerned with the nature of direction, and hence outside our metaphor.

Open systems

Many of the observations, ideas and suggestions reported on here were widely discussed and partly adopted by the C2 community in the last decade of the Cold War, partly inspired by works such as 'Gödel Escher, Bach' (Hofstadter1979) and Turing's biography. However, some of the key issues, including the cognitive versus physical split, were never satisfactorily resolved (Agar & Hughes 1999), and somehow the ideas became too closely associated with specific technologies, the general concepts being lost sight of.

Cognition

Ideas vary on the nature of cognition (Fodor 1983). Douglas Hofstadter popularized the notion of Holism as the key to understanding the human mind (Hofstadter1979)[81]. He has since developed his ideas, and used the term 'fluid' to indicate 'flexibility, mutability, nonrigidity, adaptability, subtlety, pliancy, continuousness, smoothness, slipperiness, suppleness …'. He describes the structure of water as 'flickering clusters'.

> … an electron has a hard time making up its mind which of two atoms it wishes to belong to. Since all the different hydrogen bonds are independent, they come undone at unrelated moments, so this cluster falls apart in an asynchronous manner, and even as pieces of it are decoupling, other pieces are forming new associations, so that **flickering new clusters arise out of the remnants of old ones**. All throughout any sample of water, such clusters are forming and unforming (sic) by the trillions every second. …
>
> …. **thanks to this fantastically unstable, dynamic, stochastic substrate, the familiar and utterly stable-seeming properties of wateriness emerge**.
>
> This image is ideal, I feel, for suggesting our philosophy, according to which the familiar and stable-seeming fluidlike properties of thought emerge as a statistical consequence of of a myriad, tiny, invisible, independent, subcognitive acts taking place in parallel. (Hofstadter1995)

[77] Original underlined.
[78] www.brainyquote.com
[79] Smuts is credited with introducing the British to the manoeuvrist approach (Crowe 1918).
[80] E.g. Smuts went from lawyer to Boer Guerrilla leader to C-in-C B.F. East Africa to War Cabinet Minster to being a founding father of the United Nations and (arguably) modern ecology without any apparent change in principles.
[81] When I first worked on UK C2 systems this was required reading.

This has something of the feel of 'Power to the Edge' (Alberts & Hayes 2003) about it, and is reminiscent of some fighting behaviours. As it stands, though, the aspects of water that Hofstadter emphasizes would seem to be equally true of the thoughts of someone who was mentally deranged. The use of the term liquid is intended to emphasize the need for cohesion – an appropriate degree of coherence short of paranoia[82].

Recent work

Extensive reference has already been made to the CCRP corpus, which is regarded as supporting the need for this work, while in places differing in interpretation and emphasis in detail, as one would expect for such a difficult subject. (One could even use the metaphor here, noting that even now there are different ways of viewing the subject.) Of particular import are the references to Chris Langton's work on 'the edge of chaos' (Langton 1992). This provides a computational viewpoint on many of the issues discussed here. He shows that there is an optimal degree of structure ('entropy') for viable systems, at which the propagation of influence is sustained. This is where all but the shortest conflicts sit, and what our forces have to cope with.

The work reported on here followed on from (Saunders et al 2004), noting that game theory could be applied (Howard 1999, Marsay 2000), and building on insights from Gen. Sir Rupert Smith. The key difference is that in (Saunders et al 2004) increasing complexity was taken as a reason for centralising, to retain control and the ability to give an account. If the complexity is too great then a centralised approach becomes ineffective, and so to be effective one is forced into to a more collaborative approach, even if it is no longer possible to be fully 'in control', to be efficient, or to give a coherent account even of what one's own force is doing.

NATO, under SAS 50, is exploring new concepts (SAS 2006), but has so far focussed on the classical case, where 'Quality of Decisions is characterised by [objectively defined] variables representing *accuracy, completeness, consistency, correctness, currency, precision, relevance, timeliness,* and *uncertainty'*. Its work thus has to put in the context of the wider corpus, and particularly 'Understanding C2'.

A recent RUSI journal article endorsed much of Fuller's concept of warfare, and particularly of the operational level as the locus for the manoeuvrist approach and hence for being directed and also liquid.

> Such operations also tend to highlight the **shifting overlap** that always exists in practice between the various levels, the **constantly evolving** nature of operational art, and the fact that the operational level is **not tied to a particular level** of command or even to location. (Kiszely 2005)

It also associates attritional warfare with a pedagogic approach of 'what to think' rather than 'how to think', and on conformity (coherence) "often at the expense of qualities more valuable at the operational level, such as intellect, independent-mindedness, scepticism and creativity". This suggests that the notions of 'shared awareness' and of information need to be tailored to both the type and level of warfare.

Another article highlighted the complex nature of recent, current and anticipated future operations, and criticized the current thinking on effects (Storr 2005). The liquid metaphor may be helpful here. If the situation is complex enough then the potential effects of interest may, like those in water, be emergent. In this case we shall certainly need a new intellectual tool-kit. Another article highlighted the need to 'play' through changes in context (Fry 2005):

> At the heart of successful tactics is the concept of transition – **the ability to switch** between operations of war.
>
> … expeditionary operations … represent a strategic vocation … the 'British Way of Warfare'. … How have we done recently? Not bad, but **if we cannot link our phases we will be some way short of our potential**. **This is an intellectual rather than a technological challenge** … .

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[82] Jt HLOC refers to the British 'first fuel crisis' of 2000 as an example of self-synchronisation. It is also an example where an overly coherent classical 'picture' of events would have led to the protestors being treated as subversives, like terrorists. In fact, through an understanding of holism and the potential for self-organisation enabled by the Internet and mobile phone, the crisis management team was able to equivocate, leading to a successful resolution.

[83] Developing and Leveraging **Information Superiority.**

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