ORGANIZATIONAL AUTOPOIESIS AND KNOWLEDGE MANAGEMENT

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ABSTRACT

This paper presents a biological view of knowledge and organizations formulated to provide a framework for understanding organizational knowledge and organizational knowledge management systems. This framework extends ideas based Karl Popper's (1972) epistemology of objective knowledge; Maturana and Varela's (1980, 1987) ideas of autopoiesis as extended to organizations by von Krogh and Roos (1995); Nelson and Winter's (1982) ideas of organizational evolution; John Boyd's (1976–1996) OODA (Observe, Orient, Decide, and Act) loop concept of the cybernetics of adaptation; and Ian Coombe's (1994–1999) definitions of knowledge-related terms.

INTRODUCTION

Information technology has been touted to answer to many organizational knowledge management (OKM) requirements, but its success rate has been disappointing. Recent experiences with large-scale information systems touted to answer such needs have led some influential OKM experts to argue that technology has been oversold and has not met the promise to help organizations improve their performance (e.g., Snowden 2002; Kay and Cecez-Kecmanovic 2002). Some information managers (e.g., Wilson 2002) believe OKM offers little beyond what information managers have always done. Similarly, some influential knowledge managers (e.g., Sveiby 1994, 1997, 2000) dismiss explicit knowledge (i.e., what technology can manage directly) as mere "information."

I have seen the same difficulties in my role as a documentation systems analyst for a knowledge intensive organization managing complex engineering projects, where I have been involved in selecting and implementing information systems to meet various knowledge management requirements. Some successfully resolved the problems they were intended to solve; others were ultimately cancelled at major cost to both client and supplier with no benefit achieved. The result of such problems is that many OKM practitioners focus almost entirely on the personal aspects of knowledge management, to the exclusion of IS tools for managing explicit knowledge. I believe a significant issue in the sometimes poor results achieved using information systems to manage organizational knowledge is the lack of coherent theories of knowledge encompassing both individual needs and transcendent organizational requirements, which, in turn, leads to incomplete and faulty understanding and definition of requirements for technology.

Here I summarise a theoretical framework I am exploring in a work on the evolution of knowledge management technologies and their revolutionary impacts on the nature of human cognition[2] and testing in collaborative research projects between the Monash University School of Information Management & Systems, and Tenix Defence (Owen et al. 2003). Ideas are sourced from evolutionary biology (Hall 1973), informed by my experiences in physics, cybernetics, neurophysiology, and postdoctoral work in the history and philosophy of science (Hall 1983); and more than 20 years experience managing technical documentation and documentation systems. For the last 13 years I have been with Tenix Defence, assembling and managing maintenance knowledge for the fleet of ANZAC Class frigates Tenix builds for the Australian and New Zealand Navies (Hall 2001, in press), where the framework has provided implicit guidance for developing specifications for the various documentation systems.

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2 Under the working title: Application Holy Wars or a New Reformation: A Fugue on the Theory of Knowledge.

WHAT IS KNOWLEDGE?

As also noted by Kay and Cecez-Kecmanovic (2002), the current discipline of OKM sources its theory of knowledge primarily from Michael Polanyi (1958, 1966) via Nonaka (1991, 1996; Nonaka & Takeuchi 1995) and Sveiby (1994, 1997, 2000). Polanyi's concepts of personal and tacit knowledge, where claims to know are ultimately based on belief, intuition, and faith, are pragmatically useful, but Polanyi's epistemology provides a narrow and limited basis for OKM. Despite the fact that Polanyi was a renowned physical chemist before switching his interests to philosophy, his epistemological works are generally ignored by scientists and academic philosophers (Sheppard 1999). Many scientists and philosophers concerned about the nature of scientific knowledge and its sources follow Karl Popper's epistemology (1959, 1963, 1972), which provides a much more objective approach understanding the nature of knowledge. Popper's work provides a much broader epistemological foundation for OKM than does Polanyi's, and contributes interesting insights into organizational knowledge and memory.

Popper is best known for his concepts of demarcation, i.e., criteria that can be used to formally distinguish between properly "scientific" claims to knowledge versus pseudoscience, myth, and fantasy (Popper 1959). However, his less well known later work (1968, 1972; Popper and Eccles 1977) extends the concepts of knowledge in ways that inform the development of a theory of organizational knowledge. This divides existence into three domains called "worlds". My summary of these worlds is informed by modern vocabulary, but I believe that it does not misrepresent what Popper wrote:

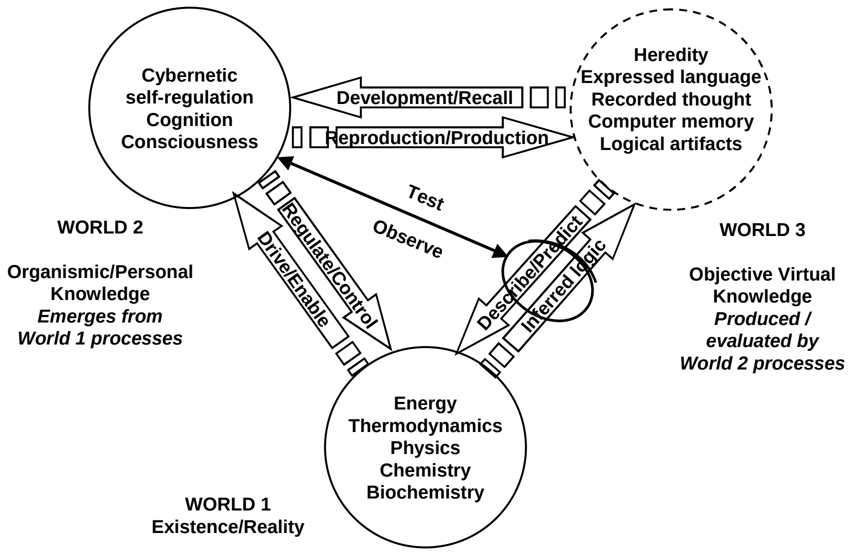

Figure 1. Graphical representation of Karl Popper's (1968) three worlds of knowledge.

- World 1 (W1) is the dynamic physical reality governed by the laws of physics and chemistry, i.e., the ultimate "truth" we try to accurately describe in our knowledge of the world.
- World 2 (W2) comprises cognition and (eventually) consciousness of living entities formed within W1. Cognitive entities try to map, represent and anticipate (i.e., in the form of hypotheses); or to "know", W1 to maintain their existence in the face of perturbations or change in W1.
- World 3 (W3) comprises the persistent logical content of expressions of cognition: e.g. heredity as encoded in DNA, logical content of computer memories, contents of manuscripts, books, libraries, etc., as expressed in language and mathematics[3]. This logical content is at the same time objective, intangible, and transcendent, in that it exists independently, both from the cognition that produces it and its physical carrier at any point in time (as demonstrated by the fact that the same logical content can be readily transcribed from one physical medium to another).

In this framework, Popper (1972:108–109) specifically states that there are

> ..two different senses of knowledge or of thought: (1) *knowledge or thought in the subjective sense*, consisting of a state of mind or of consciousness or a disposition to behave or to react [i.e., the result of cognition], and (2) *knowledge or thought in an objective sense*, consisting of [the expression of] problems, theories, and arguments as such. Knowledge in this objective sense

[3] Although Popper (1972:73-74) was prescient to include the logical content of genetic codes and computer memories as objective knowledge in W3, he did not elaborate on these inclusions.

> is totally independent of anybody's claim to know; it is also independent of anybody's belief, or disposition to assent; or to assert or to act. Knowledge in the objective sense is *knowledge without a knower*: it is *knowledge without a knowing subject.* [Popper's italics, my brackets]

These senses of knowledge correspond roughly to OKM's vernacular use of the terms "tacit" and "explicit" (Nickols 2000). For Popper, explicit knowledge is the primary focus of his epistemology; and it is, of course, explicit knowledge that information technology is best able to process and manage. By contrast Polanyi (1958, 1966) focuses most of his attention on personal knowledge.

The value of a claim (i.e., a cognitively constructed hypothesis or a "conjecture"—Popper 1963) to a W2 entity depends on how adequately it represents W1. This value is tested in action. If the entity's hypothesis about reality enables its survival in W1, the hypothesis has a positive value. If the hypothesis is inadequate, the hypothesis dies along with the entity holding it, representing the ultimate form of criticism. In time, entities holding adequate hypotheses that survive criticism increase at the expense of those failing criticism. Thus, for Popper, knowledge is the expression of a theory about reality. Consciousness, language, and writing allow individuals to articulate and share their W2 beliefs or claims as objective W3 hypotheses inferring aspects of W1 that can be "scientifically" criticised on the basis of logic and evidence external to the knowing individual. The inferences themselves are W3 objects subject to evaluation by W2 cognitive processes—i.e., by criticising them. The relative values of such artefacts of knowledge are determined by the degree to which they can be or have been criticised and tested.

Popper called this his evolutionary theory of knowledge growth. Conjectures that have been criticised by attempts to refute them (or are capable of such criticism) are qualitatively more valuable, in the sense that they do (or can) provide demonstrably adequate representations of W1, than claims that have not been (or cannot be) so tested. As new claims are made and criticised to refute and remove clearly inadequate claims, through time our store of evaluated claims grow in quality and quantity, giving us a continually improving understanding of reality.

With the advent of computer systems and electronic communications, organizations are moving increasing proportions of their knowledge into W3, where it is capable of being evaluated and managed objectively if its nature and value are understood.

AUTOPOIESIS AND COGNITION

Varela et al. (1974) and Maturana and Varela (1980, 1987) introduced the concept of "autopoiesis" (literally, self-production)[4]. Autopoiesis denotes a minimal set of properties that are necessary and sufficient to differentiate systems considered to be living from those that are not. According to Maturana and Varela, living things are dynamic systems of structurally coupled components, where the minimal properties they must have to be considered to be alive are distinctiveness, autonomy, self-regulation, and self-production. Of these properties, the most difficult to grasp is self-production. This means that the dynamic system is so organized that its constituent components collectively (i.e., metabolically) produce and maintain the system's organization. This relates to the cybernetic concept of homeostasis, which can be defined as "the capability of a system to hold its critical variables within physiological limits in the face of unexpected disturbance or perturbation" (Beer 1981:337–341[5]). Beer notes that autopoiesis is a special kind of homeostasis "...in which the critical variable held steady is *the system's own organization*" [Beer's emphasis]. Constitutive (structurally coupled) cybernetic processes embodied within the system itself provide self-regulation (e.g., Reiner 1968) in the face of perturbations. If perturbations exceed the adaptive capacity of self-regulation, the system "dis-integrates" (i.e., dies).

As noted by von Krogh and Roos (1995) organizations may also have properties of autopoiesis and cognition[6]. Varela et al. (1974), as discussed and quoted in von Krogh and Roos (1995)[7], listed six criteria that are necessary and sufficient to recognise a system as being autopoietic:

1. The system is identifiably bounded (i.e., components of the system can be clearly distinguished from the rest of the world).
2. The system is comprised of a set of parts comprising an identifiable whole.
3. The system is mechanistic, in that the component elements dynamically interact and/or act to control or transform one another. Properties of the system are generated by interactions its components and are not simply the sum of the properties of those components taken individually.
4. The components forming the system's boundaries do so as a result of their interactions with other elements that identifiably belong to the system.

[4] Maturana and Varela's work is difficult to comprehend because of its hermetically paradigmatic nature and highly self-referential vocabulary, but nevertheless rewarding. Whitaker's (2001) Web-based works are invaluable guides to understanding.

[5] From late 1971, Beer worked with Maturana in the Allende government in Chile in a conscious attempt to implement cybernetic regulatory systems until September 1973 when the government fell and Allende was killed (Beer 1981). It is unclear from Beer's account to what extent he and Maturana conceived governments to be a truly autopoietic entities.

[6] Magalhaes (1996, 1998) and Kay & Cecez-Kecmanovic (2002) give additional references on organizational autopoiesis.

[7] See also Whitaker (2001) —http://www.enolagaia.com/Checklist.html.

5. The elements forming the system's boundaries are produced by interactions of elements of the system, either by transformation of previously produced elements, or by (catalytically) transforming and/or structurally coupling non-component elements that enter the system through its boundaries.
6. All other elements of the system are also produced by the interactions of its elements as in 5 above, and if those elements which are not so produced participate as necessary permanent constitutive components in producing other components.

If all these criteria are met, then the system is considered to be autopoietic. Without citing Maturana and Varela's work or using the term autopoiesis, Stuart Kauffman (1993, 1995) covers much of the same ground at the level of mathematical modelling and molecular chemistry to demonstrate how mutually autocatalytic sets of processes can emerge spontaneously as systems become more complex.

Quoting from Whitaker's (2001) exegesis of Maturana and Varela's thinking and terminology:

> For [Maturana and Varela], cognition is a consequence of circularity and complexity in the form of any system whose behavior realizes maintenance of that selfsame form. This shifts the weight of discussion from discernment of those active agencies and replicable actions through which a given process ("cognition") is conducted (the viewpoint of cognitivism) to the discernment of those features of an organism's form which determine that entity's engagement with its milieu. ... "Living systems are cognitive systems, and living as a process is a process of cognition." (...Maturana & Varela, 1980, p. 13) [Whitaker 2001—http://www.enolagaia.com/EA.html - cognition]

In this framework or paradigm, cognition corresponds to the entity's cybernetically self-regulating activities maintaining the properties of autopoiesis. Thus, analysis should focus more on those features of the autopoietic assembly that determine its "engagement" or interactions with its milieu, than on how "active agencies and replicable actions" involved in given cognitive processes are conducted (the cognitivist viewpoint).

> A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of itself, and the process of cognition is the actual (inductive) acting or behaving in this domain. [Maturana & Varela, 1980, p. 13]
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> In other words, the foundation for the autopoietic view of cognition is not "information" as some quantum commodity available in the environment. [Whitaker 2001—http://www.enolagaia.com/EA.html - cognition]Knowledge is similarly defined:
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> In contrast with cognitivistic perspectives (wherein "knowledge" is a quantum commodity of symbolizable elements), autopoietic theory defines "knowledge" as a projected evaluation by some observer: "We admit knowledge whenever we observe an effective (or adequate) behavior in a given context, i.e., in a realm or domain which we define by a question (explicit or implicit)." (Maturana & Varela, 1987, p. 174). "The question, 'What is the object of knowledge?' becomes meaningless. There is no object of knowledge. To know is to be able to operate adequately in an individual or cooperative situation." (Maturana, 1970b: reprinted in Maturana & Varela, 1980, p. 53). [Whitaker 2001—http://www.enolagaia.com/EA.html - knowledge

In Maturana and Varela's words (1987:26), "All doing is knowing, and all knowing is doing" and, "Knowing is effective action, that is, operating effectively in the domain of existence of living beings." (p. 29). Cognition is an extension of the cybernetics of autopoietic self-regulation, that Popper places in W2. Maturana and Varela's knowledge corresponds to Polanyi's personal or tacit knowledge that is evaluated by observing results of the actions it informs; which, again, is a W2 phenomenon.

Nelson and Winter (1982) treat organizations as autonomous entities in their own rights, possessing transcendent knowledge. They argue that organizational experience is captured as organizational knowledge via unconscious "routinization" of processes and procedures, and building social and physical contexts and connections that survive the membership of particular individuals in the organization. They specifically equate this to Polanyi's tacit knowledge, and note that such knowledge is built into the constitutive structure of the organization and exists independently of individuals' knowledge.

Von Krogh and Roos (1995) argue that organizations are autopoietic, with properties of cognition and memory transcending those of the individuals comprising the organizations. They then attempt to use this to elucidate how organizations create knowledge and build organizational memories. Magalhaes (1996, 1998) and Kay & Cecez-Kecmanovic (2002) review concepts of organizational autopoiesis in organizational learning and memory. To date, the applicability of autopoiesis to these concepts has been limited because the concepts of autopoiesis and knowledge as used in the existing literature are themselves limited. Maturana and Varela considered only the very borderline between non-life and life, and thus did not consider reproduction and implications of objectively persistent forms of heredity for real-world entities. Also, the epistemologies of Polanyi, Maturana and Varela, Nelson and Winter, and von Krogh and Roos did not consider a significant role for objective forms of (hereditary) knowledge comprising Popper's W3.

Combining the ideas of organizational autopoiesis with an understanding of how organizations create and use explicit forms of knowledge in W3 gives a more complete picture of the roles and management of organizational knowledge and memory. It helps to consider how autopoietic organizations maintain their adaptation in a dynamically changing competitive environments. Col. John Boyd is a useful guide.

ORGANIZATIONS AS COMPLEX ADAPTIVE ENTITIES

Boyd (1976–1996) focussed on the roles of time and knowledge in winning competitions. Although he first developed his ideas thinking about dogfights between jet fighters, he recognised that they represent a generic cognitive framework applicable to organizations as well as individuals for achieving strategic power (Fadok 1994; Spinney 1997; Cowan 2002). His ideas are distilled in the Observe, Orient, Decide, and Act (OODA) Loop (Fig 2).

- *Observing* entails sensing a picture of external circumstances, especially focussing on changes resulting from your own or competitors' actions.

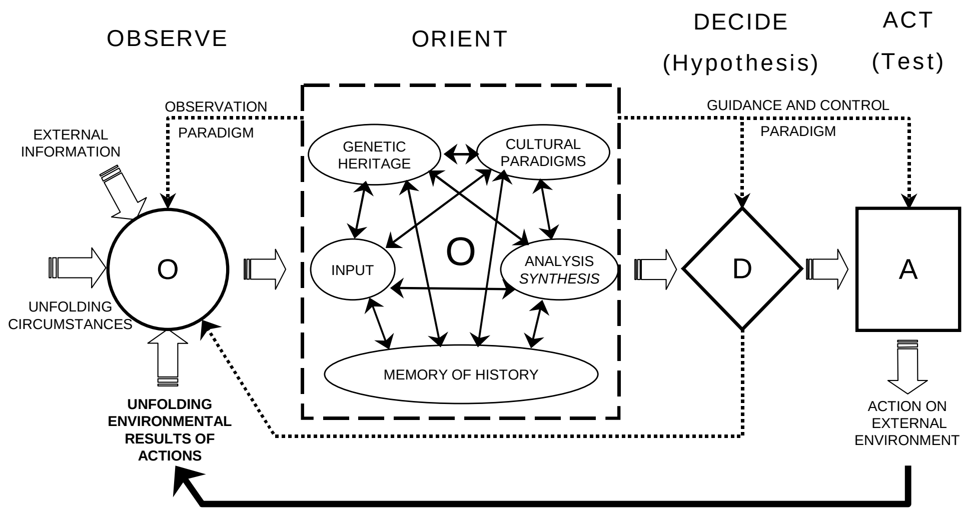

Figure 2. John Boyd's OODA Loop Concept, based on Boyd (1996: http://www.belisarius.com/modern_business_strategy/boyd/essence/eowl_frameset.htm).

- *Orienting* represents complex processes of cognition involving analysis of input from observations, as enabled by inherent capabilities, paradigmatic concepts (e.g., organizational routines) and prior knowledge reflected in a memory of history, to create hypotheses and decide an action. Boyd (1976) first described this process in Destruction and Creation. In terms of Popper's (1972) epistemology; input, cultural paradigms, and the processes of analysis and synthesis would occur in W2. Genetic heritage and memories of history represent knowledge that exists in or may be exchanged via W3. Genetic heritage is immutable within the time span of a cycle, but ultimately determines what orientation capabilities are available. All kinds of organizational knowledge may be stored and retrieved in the form of persistently recorded knowledge, which can be used to inform cognitive processing in the orientation phase.
- *Deciding* represents the formation of a hypothesis or plan of action for execution.
- *Acting* represents the actual execution of a decision.

The OODA loop is an essential aspect of the cybernetics of autopoietic entities (whether they are individuals, species or organizations)[8]. It summarises the endlessly repeating cycle of sensation, cognition, hypothesising, and testing to track and improve responses to the entity's dynamic environment. Cognition involves (cybernetic) guidance and control paradigms for observing, deciding and acting as well as for the orientation process itself. The actions of these paradigms are also observed so they may also be improved. Genetic heritage in an individual's orientation is just that: genes (W3 hypotheses) are generated by random mutation, and the developed logical content of the genes is tested over generations of natural selection. Organizational heredity is comprised of the genetic capabilities of its constituent individuals plus persistent forms of knowledge such as articles of incorporation, systems used to tag individuals as members of the organization, corporate manuals, routines, procedures, and other persistent forms of knowledge governing interactions of individuals comprising the organization that serve to maintain organizational integrity in a dynamic economic environment. Analysis and synthesis represent processes for attending to (sensory) input, assessing the history of past OODA cycles to build wisdom, relating input to existing knowledge to build intelligence, developing hypotheses, and ranking them to be selected for decision.

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[8] Karl Deutsch's (1963) ideas in applying cybernetic concepts to the self-maintenance of autonomous political organizations, which have been largely missed by writers on organizational autopoiesis, could also be taken as a valid starting point for this discussion.

A second essential consideration for autopoietic organizations or individuals is that they share environments of limited resources (funding, raw materials, food, etc.) with other entities also using the same resources. Strategic power over resources can be achieved and maintained through more effective and quicker OODA cycles than can be produced by other competitors. This is determined by the capabilities of the cognitive processes involved in orientation. By becoming aware of OODA processes and understanding how they work, we can make them work faster and more effectively, whether we are fighter pilots or organizational managers.

Coherent terminology facilitates understanding how entities create knowledge. Ian Coombe (personal communication, 1994–1999) presented definitions in the Australian Army Information Management Manual (2000 edition) comparing the epistemic values of information objects (broadly defined). These terms represent a sequence of value adding transformations an autopoietic entity can use to gain strategic power.

- *Data* is the raw state of information, i.e., unprocessed sensory observations, binary data or character strings without context or syntax. Building relationships by placing the observations or data in contextual or syntactical relationships with other data transforms the data into:
- *Information***,** or data that has been made understandable by placing it in syntax and context. Assimilating information into a semantic structure in cognitive memory transforms information into:
- *Knowledge***,** is semantically assimilated into a body of prior knowledge grounded in experience. Some knowledge can be expressed in the form of W3 objects able to be stored, processed, transmitted, and used by others. Assessing knowledge by analysing its semantic connections against prior experience transforms knowledge into:
- *Intelligence* (military sense), or knowledge that has been assessed and evaluated for its logical consistency and relationships to what is already known. Intelligence, when formulated into hypotheses and decisions for action (testing against external reality) is transformed into:
- *Wisdom*, or intelligence that has been subjected to testing in action and observed to have or not to have value in terms of predicting the results observed after the action. Wisdom is intelligence that has a proven value based on experience. Wisdom when properly applied to control the environment produces:
- *Strategic power*, which is the necessary goal of all autopoietic entities if they are to survive in competitive and variable environments.

It should be noted that various kinds of objects relating to all of these information categories can exist and persist independently as W3 objects.

SUMMARY: CONSIDERATIONS FOR ORGANIZATIONAL KNOWLEDGE MANAGERS

I follow Nelson and Winter (1982) and von Krogh and Roos (1995) in believing that most large organizations are living entities (i.e., they are autopoietic) possessing a form of heredity (comprised of W3 knowledge). Autopoiesis implies that they have cognition, memory, and knowledge that transcend the collective cognitivie processes of their individual members. It follows from this that they are capable of evolution as this knowledge changes through organzational learning (i.e., adaptive) processes.

When Nelson and Winter developed their ideas in the mid to late 1970's, information technology was still relatively primitive. Relational databases were only beginning to be implemented (Committee on Innovations in Computing and Communications, 1999). Thus, their picture was realistic then, that most organizational memory important for the autonomic regulation of organizational processes and production existed primarily in "tacit" forms, either as "routinized" knowledge in the form of W2 cognitive artefacts, or in the tacit knowledge of its members. "Tagging" of some kind (e.g., uniforms, memorised orders, etc. as were typical of military organizations and sports teams) would help to identify and bind organizational members to maintain their tacit knowledge as integral parts of the organization. Many organizations probably existed on the borderline between autopoiesis and cooperating collectives of autopoietic individuals under the managerial control of an entrepreneur. However, as routines and procedures become established to tag and control people in the organization, component members begin to act in ways that are self-productively autopoietic for the organization as a whole.

As computer technology has become more powerful and capable since the 1970s, more aspects of regulatory organizational knowledge have been externalised into W3 objects, both quantitatively and qualitatively, while still remaining readily available for cognitive processing and transformation.

Over the last 20 years there has been a strong trend to use computers to increase the epistemic value in information, from data processing, to information systems, and now to knowledge bases. Data processing involved tabulation. Information management basically involves the production, management, and maintenance of relational databases and various reporting structures based on the databases. On the other hand, knowledge management involves such tools as structured authoring to enable the assimilation of information into semantically codified knowledge and sophisticated semantic and contextual retrieval tools (Hall 2001). Examples of the variety of W3 knowledge objects that can be managed in a W3 environment include:

- Laws and internal and external standards documents
- Articles of incorporation
- Contracts and employment agreements
- Historical narratives
- Annotated links and contexts
- Databases, etc....
- E-mails and correspondence
- Records, process and procedure documents
- Plans, reports, and all other kinds of textual documents
- Computer programs such as enacted workflow systems

With the development of automatic alerting, workflow enactment systems, and the like, technology is currently moving still further up Coombe's scale of information management terms to carry out some of the processes involved in transforming knowledge into intelligence. In fact TeraText[9], developed in Melbourne by RMIT, is possibly the most powerful intelligence-gathering tool in the world. It is currently used by the US National Security Agency for signals processing. In this application, it is claimed (Aftergood and Pike 2002, Kaiha 2003) that TeraText and associated software is in every hour able to semantically process millions of phone calls, faxes, e-mails, and other types of electronic communications in W3 for intelligence, only to alert human monitors (W2) when it finds particular contexts or relationships.

Some (Wilson 2002, Snowden 2002) argue that knowledge management technology has been oversold and has not met the promise to help organizations improve their pformance. However, I believe the primary issue is that the technology has evolved so rapidly that management understanding of how to make best use of it has not kept up. It is easier for managers to deny the importance and value of W3 content and focus their attention on the much more familiar issues of managing information and people who retain W2 knowledge. Hopefully, the ideas woven together here provide for a more integrated understanding of what it is that knowledge managers should try to manage, and a new framework for using the rapidly evolving technology more effectively. If nothing else, the brief presentation of Boyd's strategic thinking as represented in the OODA loop should emphasise the importance and value of being able to effectively and rapidly work with the increasingly large volumes and valuable knowledge residing in W3.

Hall (in press) provides one example how this framework can be applied to real-world management issues.

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[9] Tenix Defence uses TeraText to semantically manage the content of logistic support documentation for ANZAC Ships and is currently implementing it for managing all product documentation for the M113 light armoured vehicles.

[10] Note: All hyperlinks were valid as at 6 July 2003.

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