Healthcare and technology: the doctrine of networkcentric healthcare

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Abstract: Worldwide costs and the disparity between healthcare in the Western world and the developing countries increase exponentially. Increased involvement of ICT allows, in similarity to the military, a transition from platformcentric to more cohesive and collaborative networkcentric operations. In the information-intensive environment of healthcare, the networkcentric approach allows free and rapid sharing of information and effective knowledge building required for the development of coherent objectives and their rapid attainment. We suggest that the application of the proposed networkcentric doctrine is arguably the best chance of changing the way healthcare is accessed, provided and managed both nationally and across the globe.

Keywords: healthcare; healthcare operations; healthcare doctrine; global healthcare; e-health; networkcentric warfare; networkcentric healthcare; ICT; Boyd; OODA loop.

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1 Introduction: the problems of global healthcare

Thomas Barnett divided the world of today into two entities – the functioning core and the non-integrating gap (Barnett, 2004), the latter characterised by different degrees of social and economic disintegration. While some may consider such a division controversial, its existence is evident in healthcare. While the Western nations (the core – *e.g.*, the European Union, the USA) strive towards affording quality healthcare for all citizens (European Institute of Medicine, 2003; National Coalition on Healthcare, 2004), within the 'gap' the access to medical services is, for the most part, either rudimentary or even nonexistent (Akhtar, 1991; Gesler, 1983). Thus, in the developed countries (such as the USA, UK, France, and Japan) there are, on the average, 19 physicians per 10 000 people. In Mexico, however, the number drops to seven, while in Tunisia there are only three physicians per 10 000 people (Gesler, 1983). In several African countries, the number is less than one (Gesler, 1983). Although per capita expenditure on healthcare is not the best indicator of money spent on actual maintenance of health (average expenditure in the EU is about 50% of the US amount, yet the Europeans appear to receive equal if not better quality of care compared to the US patients (World Health Organization Report, 2000; 2004)), in 2001 the USA spent nearly $4,900 per person. Mexico, the closest neighbour to the south, spent only $370. Mali could afford only $12 (World Health Organization Report, 2004).

As statistical quotes, these figures seem almost trivial – the disparities in funds spent on healthcare are widely known. However, their significance becomes striking when one relates the numbers to the mortality rates caused by, for example, cardiovascular disease (CVD) that is commonly associated with the 'Western style of life'. A very recent study showed India and South Africa (countries with rapidly developing economies and approximately at the middle of the healthcare expenditure list – World Health Organization Report, 2004) having "CVD mortality rates similar to those in the US thirty years ago" (Leeder *et al*., 2004). Thus, the relevance of Hart's observation (Hart, 1995), that increasing demand for healthcare is accompanied, paradoxically, by proportionately fewer resources available to provide such care, becomes particularly striking. More important, however, is the rapidly growing realisation that diseases affect nations not

only by forcing them to spend money on their elimination, but also by reducing productivity and, consequently, their gross national product as well (World Health Organization Report, 2004; Leeder *et al*., 2004; Hart, 1995).

Recently, both the 2003 epidemic of SARS and the outbreak of avian influenza demonstrated that diseases other than AIDS, malaria or tuberculosis can have devastating economic consequences on the affected nations (Lee *et al*., 2003; Fischer-Nielsen, 2003; Economist, 2003). Unsurprisingly, the members of the World Economic Forum stressed that health will have a major impact not only on the future of business but also on global security (World Economic Forum, 2002; Evans, 1993). However, the threat is far greater than regional destabilisation and the related social unrest posed by, for example, HIV/AIDS. Many of the diseases currently considered as major bioterrorism candidates (such as viral haemorrhagic fevers) are endemic to the countries lying within the nonintegrating gap of Barnett (2004). Many of these countries, characterised by the combination of poverty, poor healthcare and political/economic instability, serve as breeding grounds for philosophies that give rise to international violence (regional conflicts) and global terrorism (Barnett, 2004). It is thus obvious that the need to pay attention to the level and quality of healthcare offered to the increasingly disenfranchised and turbulent populations within the gap is not the charitable duty of Western philantrophies. Instead, the solution to 'healthcare within the gap' problem is among the essential tasks facing the governments of the affluent nations: providing better health – one of the vital ingredients necessary for the improvement of local economies – may actually improve the chances of incorporating the 'rogue' states into the functional core of the stable and secure democracies (Barnett, 2004).

2 The concept of the global healthcare doctrine

Most healthcare problems affecting the world have complex roots involving social, economic, political, and even geographical factors, whose combination provides fertile grounds for the ongoing propagation of illnesses, prevalence of trauma, and the concomitant increase in morbidity and mortality (Akhtar, 1991). Thus, unless all these elements are coherently addressed, much of the effort spent on a single disease, however deadly it may be, risks the chance of nullification owing to the emergence of another equally or even more dangerous illness. The unexpected appearance of SARS, antibiotic-resistant tuberculosis, or sporadic and entirely unpredictable outbreaks of Ebola and other haemorrhagic fevers indicate that the infusion of often very large funds into fighting a single, already prevalent illness that catches popular attention owing to its inevitably lethal consequences (*e.g.*, HIV/AIDS; see Hart, 1995) may be an indicator of well-meaning efforts rooted in Western philanthropic traditions rather than an efficient approach to the totality of issues underlying the delivery of modern healthcare in the underdeveloped world.

To remedy the current disorganisation of global healthcare effort (Wickramasinghe and Schaffer, 2005; Wickramasinghe and Misra, 2004; Wickramasinghe *et al*., 2005; Wickramasinghe and Lamb, 2002), it has been proposed that a comprehensive 'systems approach' may offer the best chance of success. Such an approach may also ensure the development of all components necessary for the solution to the wide range of present

and future healthcare issues, instead of addressing the complexities of a specific devastating illness at the expense of all other, often extremely critical, issues (Akhtar, 1991).

The governments and political bodies of both the European Union and the USA view the systems approach as the only viable option (National Coalition on Healthcare, 2004; European Institute of Medicine, 2003; Kyprianou, 2005) and, with the complexity of the tasks involved, the healthcare industry in both regions has entered the stage of a phenomenal growth (Frost&Sullivan Country Industry Forecast, 2004; Plunkett's Health Care Industry Almanac, 2004; OECD, 2004). However, it has also been said that, in the context of issues facing healthcare at the global scale, the strategies of the developed nations are rooted within their mono-cultural, ethnocentric concepts. The remedies proposed by the rich may therefore be both beyond the reach and without any relevance to the present and future problems of the poor (Fernandez, 2002).

Despite harsh criticism levelled at the developed nations for their supposed indifference to the plight of the Third World, there is no doubt that, while different, the healthcare issues facing the Western countries are serious and demand increasingly larger fiscal outlays not in order to be solved but merely (and barely) to be contained (*e.g.*, OECD, 2004; National Center for Health Statistics, 2002). To limit these expenses, Western healthcare managers place increasing emphasis on Information, Computer and Communication Technologies (IC^2T) as the most effective means to reduce costs and increase operational efficiency (*e.g.*, European Institute of Medicine, 2003; National Coalition on Healthcare, 2004). However, with the effort aimed primarily at the Western healthcare markets, the divergence between the wealthy nations and those belonging to the non-integrating gap (Barnett, 2004) increases steadily and helps to inflame the already existing tensions even further (Richards, 2004). Moreover, despite technological and economic ability to reduce many of the healthcare-posed burdens of the developing world, the absence of adequate profit incentives limits the eagerness of the corporate world to participate with equal vigour in global programmes as well as in those of solely Western national/regional significance (Fernandez, 2002).

The absence of a clearly defined 'global perspective' and foresight among the Western nations, and our failure to incorporate into the future plans anything beyond the most obvious, are not typical of healthcare alone. The inability of the West to detect, analyse and counteract the growing dissatisfaction with its policies is among the principal causes underlying the explosive emergence of anti-Western sentiment, religious extremism and – ultimately – international terrorism as the sole means available to the populations of the gap to attain emotional if not economical 'parity' with the developing countries (Barnett, 2004; Onen, 2004). The political destabilisation that typically accompanies these extreme forms of protest weakens the economies in the underdeveloped regions, promotes escalation of poverty, and leads to an even greater decline of their already meager (or practically nonexistent) healthcare systems (Akhtar, 1991). Consequently, despite substantial funds provided by the multinational Western sources (US Mission to the UN Release, 2002; Li and Easrman, 2003; Ma'ayeh, 1999), the attempts to establish comprehensive solutions to the healthcare needs of the developing and underdeveloped world continue to fail (Zupan, 2003; Pal and Mittal, 2004; Afford, 2003; Attaran, 2004).

However, even in countries like the USA, the inefficiency of several existing healthcare/healthcare-related processes is apparent. The inability to address meaningfully

some of the important problems faced by US healthcare resulted in the proposal for either their substantial reduction or disbandment (White House Budget Proposal 2005–2006,[1] refs. OMB/DHHs, 2005; Spratt, 2006). At the international level, the inefficiency of the highly fragmented programmes (governmental and private) in addressing even the most urgent aspects of global healthcare, points at the very urgent need to develop a new set of rules (Barnett, 2004; Onen, 2004; Olutimayin, 2002; Banjeri, 2004) for healthcare – the 'doctrine of global health'.

3 The doctrine of networkcentric operations

In military terms, 'multinational doctrine' means a set of "fundamental principles that guide the employment of forces of two or more nations in coordinated action toward a common objective. It is ratified by participating nations" (DoD, 2005b). Consequent to the national or international policies, doctrine is a set of authoritative rules governing practical execution of these policies. Thus, while doctrine 'requires judgement in application' (DoD, 2005a), it defines the overarching rule set for the deployment of adequate and relevant resources required for rapid and maximally effective implementation of national/international policy objectives. The significant stipulation that the practical implementation of a doctrine 'requires judgement' provides the flexibility necessary for the development of a measured response whose intensity is commensurate to the intensity of the confronted problems or threats. More importantly, the development of a doctrine requires comprehensive study of all factors that characterise the operational space within which the doctrine is to be implemented (political, economic, social, military, geographical, *etc*.). All of these factors may have a significant impact on the conduct of field operations and, hence, will determine not only the structure and composition of the deployed forces, but also the main direction of their thrust towards the attainment of the objective.

Information superiority is a critical component of military operations and, realising the essential role of IC^2T in providing the modern commander with structured information, the US Department of Defense developed the doctrine of 'networkcentric warfare' (Cebrowski and Garstka, 1998). The doctrine calls for the development of interconnected information grids that, together, constitute a sturdy network that facilitates information sharing among all participants within the battlespace (Cebrowski and Garstka, 1998; Stein, 1998). Consequent to improved information sharing is the enhancement of its quality and integrity which, in turn, escalates the level of situational awareness. The latter is the foundation for better collaboration among the involved entities, their self-synchronisation and operational sustainability. The overall effect is a dramatic increase in mission effectiveness (Cebrowski and Garstka, 1998). The success of early trials with the doctrine of networkcentric operations led to its adaptation by several other armed forces across the globe. More importantly, in similarity to other concepts originated by the military (of which the internet is the most classical example), the doctrine begins to find its place in the modern, IC^2T-driven business world (Cebrowski and Garstka, 1998).

4 The conceptual framework of networkcentric operations

The doctrine of networkcentric operations finds its origins in the pioneering work of Boyd (1987), who analysed the process of decision-making, interaction with and control of a fast-paced and unpredictably changing environment. Originally aimed at the war-fighting community, Boyd's OODA Loop revolutionised many aspects of modern combat and found many practical uses in a wide variety of civilian scenarios/applications, including medicine (von Lubitz *et al*., 2004). The practical application of OODA Loop-based interaction is straightforward in the context of cohesive environments of limited size (microenvironments) that either evolve rapidly but have a relatively low range/complexity of information inputs or are characterised by a large complexity of information inputs but a relatively slow evolution speed. The interaction with complex macroenvironments, particularly those characterised by a very rapid revolution cycle and a vast array of multispectral information inputs, becomes exceedingly difficult if not impossible in the absence of automated assist systems (Endsley and Kaber, 1999): information overload forces the operator into subjective selection of *seemingly* relevant inputs while ignoring others that *appear, at the time of the analysis*, to be irrelevant (Endsley and Kaber, 1999; Lehto, 1991; Prietula *et al*., 2000; Tole *et al*., 1982). Consequently, responses to the objective environmental pressures become increasingly founded on the subjective interpretation of the incoming information and the possibility of a catastrophic error increases exponentially. A striking example of such a situation is provided by the '911 Report' (2004), which demonstrates how fragmentation and the lack of an effective information sharing/analysis network connecting all actors within the shared operational space resulted in the dismissal of highly relevant yet seemingly unrelated inputs that predicted the attack.

Large-scale healthcare operations take place a within highly complex and rapidly changing macroenvironment incorporating politics, economy, population shifts, existing and emerging diseases, *etc*., all of which are characterised by their own dynamics. Rather paradoxically, the daunting task of making large-scale healthcare operations effective, focused and economically feasible may be simplified by adopting solutions found, tested and practically implemented in warfare.

5 Warfare and healthcare

The fundamental rules of warfare have remained unchanged ever since the earliest known treatise on the conduct of war (Sun-Tzu, 1910; see Table 1). The rules indicate that clear definition of the objective defines all other elements of action, although effective attainment of the objective is contingent on adequate, reliable and timely information. The latter determines the type and size of the required force, the manner in which its actions are executed, *etc*. Most, if not all, of the same rules can be applied with equal effectiveness to almost any other activity executed in a rapidly changing ultracomplex environment, such as business operations (Khoo-Kheng, 2002; McNeilly, 2000; Chen, 1994).

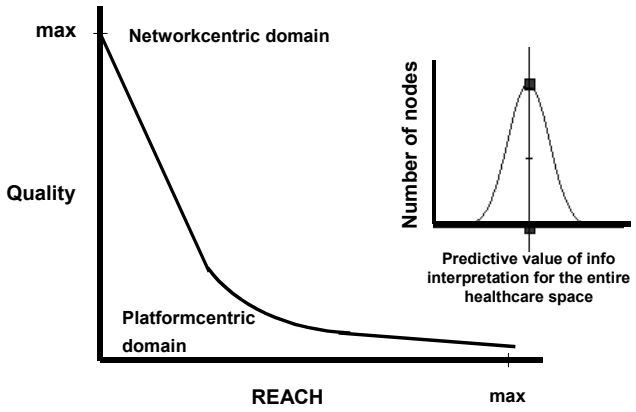
Table 1 Fundamental rules of warfare

Rule	*Application*
Objective	The principal goal of the effort; Attainment of the objective ends all actions related to that task
Offensive	Effort to attain the stated goal; Sizing the initiative (staying within the OODA Loop at all times) is critical to that effort
Concentration of force	Concentration of *all* resources at the decisive time and place
Economy of force	Application of minimum adequate resources needed to control unimportant segments of the operational space
Maneuver	Exploitation of all elements within the environment to one's advantage
Unity of command	Subordination of mission executive powers to a single, operationally most relevant, rather than multiple command bodies
Security	Assurance of accuracy of information and its safety
Surprise	Ability to act when, where, and in a manner least expected by the adversary and exploiting all weaknesses of the opposition
Simplicity	Development and implementation of all plans, guidelines, *etc*., in a manner as direct, uncomplicated, and unambiguous as possible

Traditionally, healthcare operations (as much as military ones – see Cebrowski and Garstka, 1998) are platformcentric, *i.e*., based on, and exploiting the exclusive properties of the employed system, be it a diagnostic device (*e.g.*, ultrasound or MRI), a healthcare provider (nurse, physician) or an electronic data base (*e.g.*, electronic patient record, billing/reimbursement system or knowledge base). Useful on a small scale, such a platformcentric approach introduces the element of operational uncertainty, whose significance and detrimental impact increase exponentially in relation to the magnitude of the operation (operational space) within which it is employed (Alberts *et al*., 2000). In complex operational space, the limitations of the platformcentric approach derive primarily from the inadequate information gathering and manipulation capabilities of non-cooperating, individual systems. Such limitations severely degrade the integration of multispectral information inputs that, in the context of healthcare, comprise not only purely medical but also political, economic, geographical, ethnographic or temporal sources, to mention just a few. Environmental complexity may be increased even further by the frequent presence of multiple actors (agencies, governmental bodies, global organisations, *etc*.) that operate within the same space but use a wide variety of platformcentric tools. As a consequence of the resulting chaos, the attainment (mission) of the goal (objective) is uncertainty driven rather than information driven (DoD, 2001a). The rapid divergence between the progressive European centralisation and US decentralisation of healthcare (European Institute of Medicine, 2003; National Coalition on Healthcare, 2004) consequent to the employment of a wide range of platformcentric solutions proposed as a remedy for the existing problems (*e.g.*, Terpstra, 1989; Pappaioanou *et al*., 2003; Tzanis, 1998; Hironaka, 1992; Report on 13th Intl. Conference on AIDS, 2000; Domin, 1998; Russo, 2000; Lacroix, 1999; Jennings and Clark, 1997; Thompson *et al*., 1996) is probably the best proof of uncertainties that drive healthcare policies in these two otherwise broadly homogeneous regions.

Another complication inherent to platformcentric operations is the decrease in information integrity and quality (the latter with its key elements of content, accuracy, timeliness and relevance) as a function of its reach (Alberts *et al*., 2000; DoD, 2001a–b). In the present system of healthcare information dissemination, academic medical centres (platforms) constitute probably the best source of relevant and accurate information (MacLeod, 2003; Lee *et al*., 2003; Abels *et al*., 2004; McGowan *et al*., 2004; Morse, 2003). However, at the level of the individual healthcare provider (operator), the quality of the available information on some of the most fundamental aspects of medicine is frequently substandard (Maloney *et al*., 2005; Murphy *et al*., 2003; see Figure 1).

Figure 1 Information quality versus information reach



Information quality decreases with its reach. Each system contains a definitive amount of information that characterises it and, as long it remains within that system, the describing information has maximum quality. Whenever the information is retrieved, it is exposed to subjective manipulation/interpretation due to incomplete extraction, misinterpretation, *etc*. Each subsequent transfer of the retrieved information may be subjected to further deterioration in quality both at the transmission stage (incomplete transfer, imprecise transfer, *etc*.) and the recipient (for example, owing to failure to receive all relevant information, retention of irrelevant nonrelevant information or misinterpretation). The loss is cumulative and, with the increasing reach (*i.e*., the number of transmission-reception stages), the deterioration can be very significant. At the outer limit of reach, the information available to the recipients may be wrong, incomplete or even totally meaningless, although the recipient may not be aware of it. Note, however, that even at the maximum reach, a fraction of quality information is still present (intelligence services often derive pertinent information describing operational target from very poor content sources, as poor as propaganda broadcasts, government controlled newspapers, *etc*.). In medicine, the decrease in information quality as a function of reach is best seen on the web, which provides maximum distribution range, where much of the information is either outdated or (to a varying degree) incorrect (Maloney *et al*., 2005; Murphy *et al*., 2003; Perez-Lopez, 2004; Haddow and Watts, 2003; Blair, 2004).

Deterioration of quality as a function of information reach is typical of platformcentric operations, where each platform collects information from the environment using subjective collection rules, generates information using subjective criteria of validity, and disseminates transformed information in a manner either fully or partially incompatible with the gathering capabilities of other platforms. The combined output of all platforms is chaotic and may be highly fragmented or even partially/completely incorrect. The operational effectiveness within the healthcare space is consequently greatly affected (Kulkarni and Nathanson, 2005).

The networkcentric approach supports multidirectional and unrestricted flow and sharing of multispectral information, both raw (deriving from sensors) and already processed (at the level of individual nodes) among all constituents of the network. Like the platformcentric approach, each individual information-processing constituent of the network (node) may handle information in a subjective manner. However, in order to be effective, the network must consist of a very large number of interconnected, information-sharing, heterogeneous nodes, since the analysing power of the network increases as the cube of the number of active nodes (Metcalfe's Law, see also Kulkarni and Nathanson, 2005). Consequent to such an increase is the reduction in time required for the most objective (and plausible) interpretation of multispectral information inputs. With a very large number of nodes contributing to such interpretation, and the Gaussian distribution of the resulting interpretation variants, the network will be able to align automatically (self-organise and self-synchronise) along the most plausible solutions and meaningful activities that, in turn, will permit the highest chance of reaching the objective. Fine tuning of the alignment (*i.e.*, selection of the best fit from the solutions available among those to the right of the vertical line) takes place within the cognitive domain of the network (see text and figures for further details).

Altogether, the present uncertainties about the future direction of both national and global healthcare indicate the acute need for transformation that, in similarity to the definition provided by the US Joint Staff Whitepaper (DoD, 2001b), will result in the evolution and deployment of capabilities leading to revolutionary advantages in the dissemination of and access to healthcare.

6 Doctrine of networkcentric healthcare

While the OODA Loop provides the essential framework for interaction with and influence on complex sets of macroenvironments, neither an unaided operator (*i.e.*, a provider, agency or government) nor an operator interacting with such sets through platform-based systems would be expected to succeed (Alberts *et al.*, 2000). The richness of the information produced by the set of macroenvironments, the rapid pace of its change, and the broad range of its sources would overwhelm the capacity for adequate information analysis and the subsequent extraction of action-relevant conclusions. Consequently, successful interaction with complex sets of macroenvironments (macroenvironment galaxies) such as global healthcare (which comprises a vast array of independently identifiable macroenvironments, *cf.* 1) presents an insurmountable task *unless assisted by a highly sophisticated, multilayered network of IC^{2}T that incorporates a full range of telecommunication platforms, sensors, data-storage elements, analytical nodes and dispersed access points, the operation of which provides flexible command and control and rapid response capabilities*. A similar network and its operations constitute the cornerstone of the *networkcentric doctrine of warfare* currently

implemented by the US Department of Defense and several other defence establishments across the globe (Network Centric Warfare Asia, 2004; Network Centric Warfare Europe, 2005).

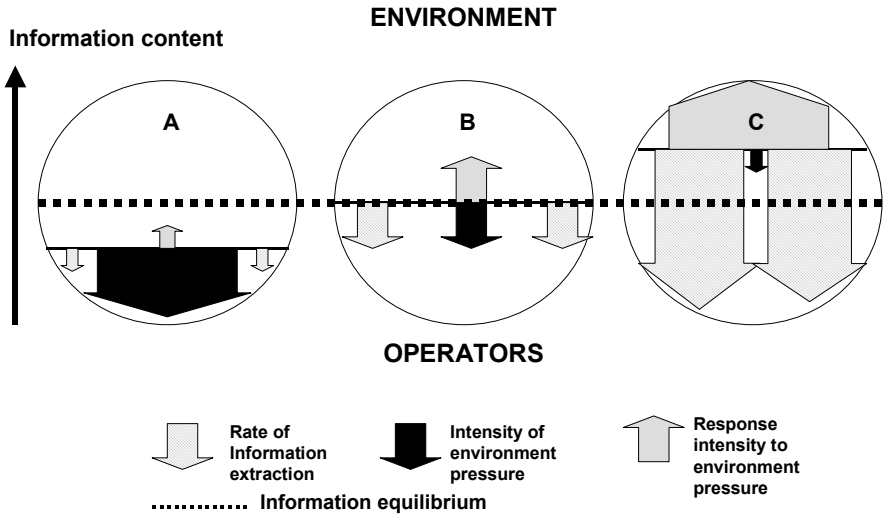
With small modifications, the military doctrine of networkcentric warfare can be easily reconfigured into *networkcentric healthcare.* While introducing such a concept, it is important to remember that the notion of networked operations is not alien to healthcare and that the use of, *e.g.*, CHINs, LAN or WAN-based electronic patient records or billing/reimbursement systems connecting several units within the same administrative entity, such as an HMO or a hospital system, is steadily increasing (Overhage *et al*., 2002; Carlie and Sefton, 1998; Overhage, 2004; Kulkarni and Nathanson, 2005). However, since networks represent distinctive and disconnected entities, their operation is, essentially, platformcentric. Platformcentricity of healthcare IC^2T operations and the concomitant fragmentation and broad incompatibility of individual effort have major influence on the access range to- and sharing of high quality information existing within individual platformcentric systems (Valdes *et al*., 2003). Consequently, although providing very significant advantages to the local users (Overhage *et al*., 2002; Carlie and Sefton, 1998; Overhage, 2004; Kulkarni and Nathanson, 2005), the overall impact of electronic information systems on either national or international healthcare operations continues to be relatively limited (Valdes *et al*., 2003).

Networkcentric healthcare, like its military equivalent, has roots in networkcentric computing (von Lubitz and Wickramasinghe, 2005e), whose practical development has been greatly facilitated by the rapid progress of various areas of IC^2T (*e.g.*, HTML, TCP/IP, Web, JAVA, XTML – see Hironaka, 1992; Valdes *et al*., 2003). In warfare, as much as in business, networkcentric computing is employed as a source of the information superiority necessary to gain competitive advantage. In healthcare, rather than providing competitive advantage, information superiority allows:

- clear definition of short- and long-term healthcare objectives
- definition of missions required to attain these objectives (offensive)
- concentration of forces needed to execute the mission and attain the objective
- determination of force economy that will prevent resource dissipation
- exploitation of all characteristics of the operational environment (politics, economy, social structure, diversity of infrastructure, *etc*.) to attain the objective (the equivalent of military maneuvers)
- definition of unified command (who, what, where and how) rather than its fragmentation (all doing the same thing without a clearly defined objective, planning, coordination, control and communication, resulting in chaos and resource dissipation)
- security ensuing from the collection and dissemination of uniformly high-quality, relevant information inaccessible to intruders without 'the need to know'
- instantaneous responsiveness to suddenly emerging healthcare crises (equivalent to the military advantage of surprise action)
- simplicity in plans, guidelines and their operational implementation.

In summary, in healthcare (as in war), information superiority (Figure 2) provides asymmetric operational advantage that favours the operator and allows him to dictate the direction and tempo of all activities in a collaborative yet highly coordinated manner that facilitates reaching the objective as expeditiously, effectively and economically as possible.

Figure 2 Role of information asymmetry in healthcare operations



The role of asymmetry and information superiority in healthcare operations. In Figure 2A most of the information contained within the healthcare environment is inaccessible to the operators (scientists, providers, managers, *etc*.) owing to inadequate technology, unstable political conditions or insufficient resources (pre-World War I state). Limited availability of information about the environment confers an operational advantage to the environment, and operators are helpless in the face of healthcare cataclysms (*e.g*., 'Black Death' during the Middle Ages, pan-European spread of syphilis or more recently, the influenza pandemic of 1918).

In Figure 2B, the retrieval of multispectral information from the environment is greatly enhanced owing to the improvements in medical sciences and information technology, improved political/economical stability, *etc*. As a result, healthcare managers are equipped with better tools and knowledge to withstand pressures caused by perturbations within the healthcare environment, but not to prevent them. The present healthcare space is characterised by such an equilibrium of effects: epidemics (AIDS, SARS, antibiotic resistant tuberculosis, *etc*.) or adverse events (population growth, population aging, erupting pockets of political instability, *etc*.) upset the equilibrium temporarily, but the improvement in the retrieval of information from the environment allows implementation of sufficient measures that limit the impact of destabilising factors and restore the equilibrium state.

Figure 2C shows networkcentric interactions which allow rapid extraction of information from a multiplicity of sources within the environment (Observation stage of the OODA Loop) and its networked processing (Orientation stage). The cumulative effect causes the shift in the balance of information content from the environment to the operators (attainment of information asymmetry). Networkcentric operations allow rapid, incisive decision-making (Determination stage of the Loop) and concentration of thrust (Action stage) at the most significant threats posed by the environment. In the networkcentric environment, the speed of information retrieval accelerates continuously. However, owing to the large number of processing nodes within the network, information overload does not ensue. An important advantage of the networkcentric approach is its facilitation of the elevated rate at which high-quality knowledge is generated. The latter permits continuous goal-oriented refinement of management actions within the entire healthcare space (exercise of unified command and control of the environment) both at the present and future operational stages.

In similarity to all other activities conducted in complex environments, healthcare operations affect three distinct entities, *i.e*., technology, processes and people (von Lubitz and Wickramasinghe, 2005d). Consequently, healthcare operations are conducted within three mutually interconnected and functionally related domains (von Lubitz and Wickramasinghe, 2005d; Garstka, 2000; see Figure 3).

Figure 3 Three domains of healthcare operations

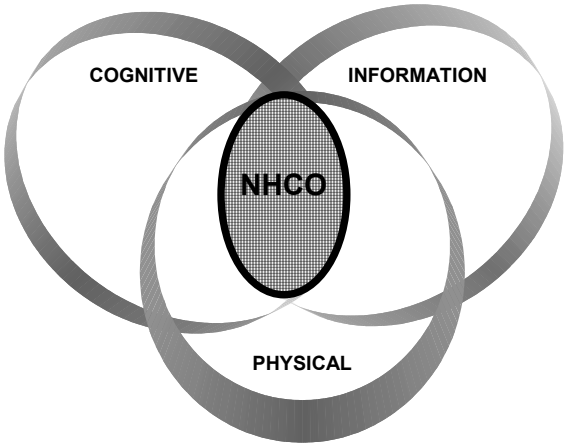


Diagram of the relationship among the operational domains in healthcare. Networkcentric healthcare operations (NHCO) exist only in the territory where all three domains overlap. The physical domain overlaps both the cognitive and information ones and contains the essential ingredient of networkcentric operations – the Worldwide Healthcare Information Grid (WHIG).

- The *physical domain* encompasses the structure of the entire environment healthcare operations intend to influence directly or indirectly, *e.g.*, elimination of disease, fiscal operations, political environment, patient and personnel education. The data within the physical domain are the easiest to collect and analyse, especially as they relate to the *present* rather than the future state. It is also the territory where all physical assets (platforms) such as hospitals, clinics, administrative

entities, data-management facilities, and all other physical subcomponents (including people) reside. Cumulatively, the physical domain represents *the current state of healthcare reality*.

- The *information domain* contains all elements required for the generation, storage, manipulation, dissemination/sharing of information, and its transformation and dissemination/sharing as knowledge in all its forms (explicit, tacit, germane, *etc.*; see Garstka, 2000). Within the information domain, all aspects of command and control are communicated and all sensory inputs gathered. The sensors exist as a variety of entities (people and devices) and the sensor output may have a variety of forms and different degrees of sensitivity (*e.g.*, data from a direct healthcare provider/patient encounter, a CT scan, electronic health records, billing/reimbursement record, regional/national per capita healthcare expenditure). While the information existing within this domain may or may not adequately represent the current state of reality, all our knowledge about that state emerges, nonetheless, from and through the interaction with the information domain. Likewise, all communications about the state of healthcare take place through interactions within this domain. Because of these attributes, the information domain is particularly sensitive and must be protected against intrusions that may affect the quality of information contained within this domain. It also must be defended from misuse/exploitation by outside entities (*e.g.*, commercial use of electronic patient records in insurance transactions or hiring procedures).
- The *cognitive domain* comprises all human factors that affect operations, such as education, training, experience, political inclinations, personal engagement (motivation), 'open mindedness', or even the intuition of individuals involved in the relevant activities. All these represent highly intangible quantities that are difficult to measure but form the basis for the selection of right timing, right place and right effect of all actions undertaken within the healthcare 'battle space' (Boyd's 'Schwerpunkt' – *cf.* Boyd, 1987; von Lubitz *et al*., 2004). Even in the presence of well-developed decision support systems provided by the information domain, it is within the cognitive domain that deep situational awareness is created, judgements made, and decisions and their alternatives are formulated. It is at this level that the results of the Determine stage of the OODA Loop (command intents) are converted into meaningful action that will, in turn, affect the following revolution of the loop. The cognitive domain also contains elements of social attributes (*e.g.*, behaviours, peer interactions) that further affect and complicate interaction with and among other actors within the operational sphere. Difficulties in metrics relevant to the cognitive domain notwithstanding, a body of experimental studies begins to emerge that will ultimately provide close quantitative relationships to other domains that govern the healthcare operations space (*e.g.*, Bodner and McMillen, 1986; Roberts and Clifton, 1992; Back and Oppenheim, 2001; Newby, 2001; Wetherell *et al*., 2002; Abel-Smith, 1989).

The doctrine of networkcentric healthcare operations (NHCO) is thus defined as:

> "unhindered networking operations within and among all three domains that govern all activities conducted in healthcare space and are based on free, multidirectional flow and exchange of information without regard to the operational properties of all involved platforms or platform systems, and utilizing all available means of IC^2T to facilitate such operations".

The relations defined by the doctrine are shown schematically in Figures 3, 4A, 4B and 4C.

The essential physical foundation of NHCO is the WHIG, which allows full, unhindered sharing of information among individual domains, their constituents and among constituents across the domains. In order to perform such a function, the WHIG must consist of an interconnected matrix of IC^2T systems and capabilities (including communication platforms, data collection, storage, manipulation/dissemination and sharing), associated processes (such as information and knowledge storage and retrieval, management and their dissemination/sharing), people (*e.g.*, healthcare providers/investigators, administrators, economists, politicians, lawyers, IC^2T personnel) and agencies (governmental and non-governmental organisations or NGOs at the local/national/international level).

Although the required technology and individual components of WHIG already exist, the grid needs to be constructed using universally shared operational and security standards and protocols allowing unhindered access to all actors within the healthcare space (Figures 4A, B, C). Once developed, the Grid will facilitate information sharing and enable joint development of objectives, precise characterisation of missions necessary to attain these objectives, allocation of adequate resources and continuing monitoring of progress. The latter will, in turn, permit timely interventions (*e.g.*, modifications of the mission profile, changes in resource allocation) assuring unhindered execution of the task. The presence of WHIG is also essential for the development of unified command structure and synchronisation of currently non-related efforts conducted within the same segment of healthcare space, with the consequent improvement in the economy of effort and its concentration. That such controls are required has been demonstrated by several studies showing that, in the developing countries in particular, the currently disorganised conditions of healthcare aid often result in inefficiency and inappropriate application of the available resources (Abel-Smith, 1989; Howard, 1991; Collins and Green, 1994; Michaud and Murray, 1994; Schneider and Gilson, 1999; Buse, 1999).

The creation of WHIG will also significantly improve the critical process of data fusion necessary for the development of enhanced awareness of the healthcare space. It is important to note that WHIG facilitates both the fusion of multispectral data (allowing detection and identification of the emerging healthcare threat) and sensor data fusion (allowing tracking of the healthcare threat in space and time). Hence, awareness of the healthcare space shared among all actors with access to the grid will have a critical facilitating role in very early interception of potentially catastrophic events (*e.g.*, pandemics) or timely mitigation of adverse health trends (similar to, for example, the entirely unexpected emergence of CVD as a major source of mortality in the developing countries; see Leeder *et al.*, 2004).

Considering the multifaceted functionality of WHIG, one of the measures of its effectiveness will unquestionably be its ability to convert presently fragmented efforts into a fully integrated and interoperable 'force' capable of a joint, unified, goal-oriented execution of stated objectives through a uniform access to and sharing of information and knowledge. Another key measure of the effectiveness of WHIG-based networkcentric activities will be their impact on the overall rate of progress of healthcare operations and their economy, reach and range, all measured at both national and global scales.

Figure 4 A) Networkcentric healthcare operations: World Health Information Grid (WHIG); B) WHIG multi-segment structure; C) WHIG: major components

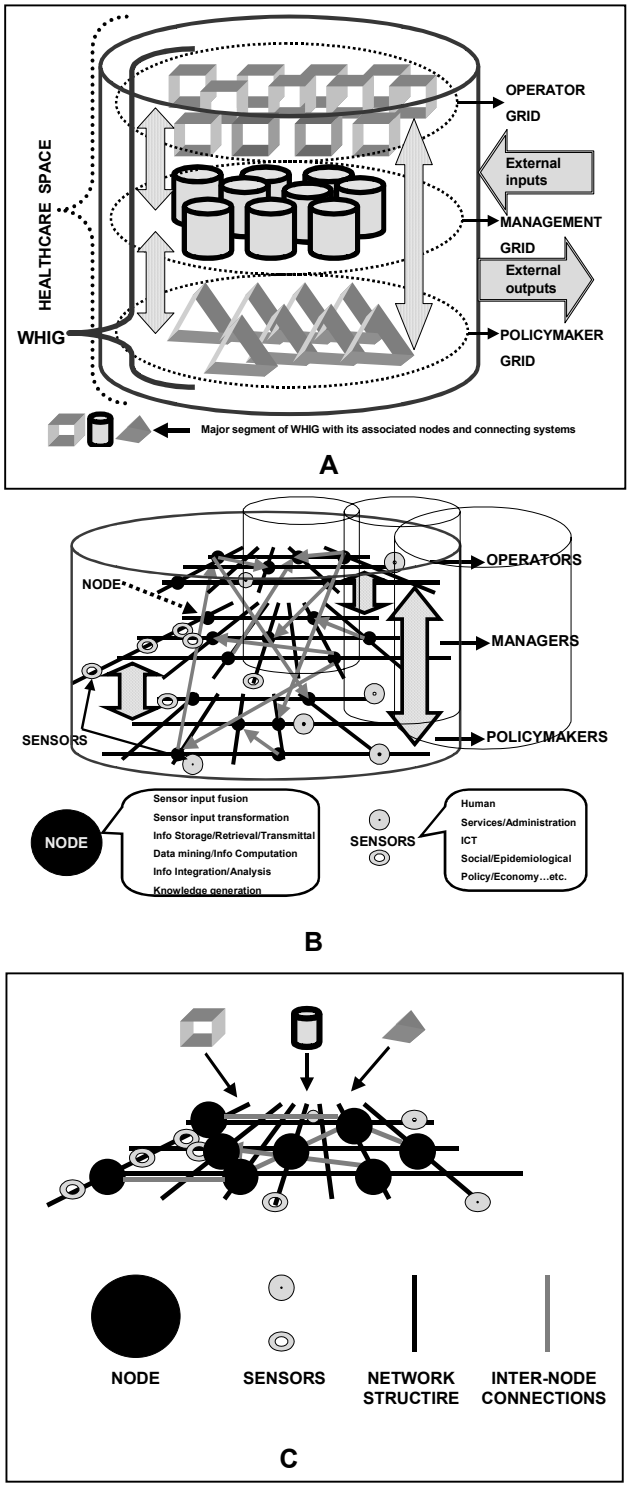


Diagram of the WHIG. The healthcare space (Figure 4A) contains three principal interconnected subgrids of operators (*e.g*., healthcare providers, agencies), managers (national and international agencies, organisations, healthcare-related businesses, *etc*.) and healthcare policymakers (national and international legislative bodies, governments, and government associations such as EU, WHO, OAS). The vertical arrangement of subgrids (Figures 4A and 4B) is for clarity only, and does not indicate a hierarchical order of activities. On the contrary, absence of definitive hierarchies of domains and intra-/interdomain systems is one of the major attributes of the networkcentric operations that facilitate information flow and sharing.

Each grid comprises an unlimited number of information processing nodes (Figures 4B and 4C), and each node consists of a mix of several subcomponents (Figure 4C). The nodes ensure that the information flows freely and is shared within and among the three sub-constituents of the WHIG. Healthcare sensors, whether human (*e.g*., providers, relief workers, economists) or electronic (*e.g*., patient records, billing systems, demographic databases), are embedded within each subnetwork (Figure 4C) and provide continuous input about the state of the healthcare space to all constituents of the grid. WHIG can, if needed, receive inputs from sources outside but relevant to the management of healthcare space, (*e.g*., governments, economic organisations such as the World Bank or USAID, military, law enforcement). WHIG can also generate outputs outside healthcare space when such outputs are relevant to the overall effort at the national/global development and stability.

Contrary to platformcentric operations, WHIG does not promote the development of a rigid, inflexible, and hierarchical command and control structure. Instead, WHIG promotes real time access to all relevant information/knowledge available within the entire healthcare to all entities within the healthcare space. Hence, it also introduces an unprecedented flexibility in the managerial structure. The existence of such a flexibility is the imperative ingredient in support of the rapid transfer of command and control authority among the involved entities as dictated by changes in mission profile or the operational relation of the mission to the stated objective. At the logistic level of healthcare operations, WHIG plays a critical role in the creation/adjustment of the 'force mix' required to attain stated objectives, and in the timeliness and adequacy of the resource allocation to support the ongoing and planned mission(s).

7 Conclusions

The currently disorganised state of global healthcare indicates the need for the development of an operational doctrine that will provide a unifying set of rules for all future efforts. The doctrine of networkcentric healthcare operations proposed in our paper offers several advantages. First of all, a similar concept has already been implemented with significant success by the military establishment. Hence, the 'lessons learned' can be readily adopted into the civilian environment. More importantly, however, by permitting free flow of information among currently disconnected entities and fields of healthcare operations, the networkcentric doctrine allows us to create the state of information superiority. The latter is a prerequisite for the rapid development of the currently absent comprehensive, multifaceted and unified body of knowledge necessary to conduct healthcare activities in a manner that addresses present inequalities through a consistent knowledge-based effort rather than, as is presently being done, through the erratic application of ever larger amounts of money.

Some components necessary for the practical implementation of networkcentric healthcare already exist, while others, such as WHIG, will need to be developed.

Application Software Provider (ASP)-based activities will need to be implemented on a vastly larger scale than today in order to support regions with lesser technical capabilities. Also, many of the existing platforms (*e.g.*, the wide variety of the existing HER types) and platform systems (such as healthcare organisations, national or regional systems) will need to be converted to the level suitable for networked operations. Similarly, new security approaches will need to be devised, and both legal and ethical matters that will unquestionably arise will have to be addressed. We have already addressed some of these issues in other papers and the interested reader is referred to these publications (*e.g.*, von Lubitz and Wickramasinghe, 2005a; von Lubitz and Wickramasinghe, 2005b; von Lubitz and Wickramasinghe, 2005c; von Lubitz and Wickramasinghe, 2005d; von Lubitz and Wickramasinghe, 2005e; von Lubitz *et al.*, 2005). While more articles dealing with the detailed aspects are forthcoming, there is no doubt in our minds that, similarly to the development of networkcentricity in the defence establishment, a broad discussion and further elaboration by specialists in many relevant fields is necessary before the concept of NHCO is implemented on a large, international scale.

The deplorable consequences of hurricane Katrina underline both the need for healthcare operations based on networkcentricity and the fallacy of the platformcentric approach to complex healthcare activities. The essentially total collapse of the first-responder system, multiple deaths at even the most sophisticated healthcare facilities and spectacular logistical failures combined with the truly magnificent effort of individual providers clearly show that healthcare operations cannot be based on speculation devoted to the utility of HER or issues of reimbursement. The problems of healthcare, particularly at a larger, national or global scale, encompass a range of widely varied elements that together constitute the continuum of healthcare and its intimately related activities. Each and every one of these constituent activities is characterised by its own attribute of specific information and knowledge that is strictly domain pertinent and, viewed in separation, may have a minimal or no relevance to either access, delivery or quality of the delivered care. Yet failure to incorporate such information and knowledge in the healthcare response to a crisis (and even without major cataclysmic events the world healthcare is, indeed, in crisis) invites disaster. The devastation of the Indian Ocean rim by the tsunami of 2004 or the collapse of New Orleans serve as forcible examples of healthcare managerial failures caused by information/knowledge-management and operational acuity deficiencies that networkcentric approach may help to eliminate. In both cases, the relevant information was inaccessible to its users at the time of the greatest need either because individual platforms were incapable of sensing its existence elsewhere, accessing it efficiently, or simply because of inability to communicate with each other altogether (*e.g.*, problems related to the deployment of personnel and support resources at the most critical, immediately postevent time and the collapse of telecommunications systems).

Consequently, the informational chaos weakened the already feeble command structure and, like in a war, resulted in a rout.

Clearly, while the defence establishment already demonstrated the validity and value of networkcentric operations, NHCO awaits such a test. There is no doubt that practical implementation of NHCO is daunting and can be performed only within organisations that, in similarity to the armed forces, are characterised by a well-defined organisational structure, uniformity of goals and clearly defined missions, *i.e.*, major corporate healthcare entities, states and government-supported international organisations (WHO,

UNICEF, World Bank, *etc*.). We believe, however, that the initial deployment of NHCO ought to take place as a small-scale effort (at the level of a corporate healthcare entity or within an international healthcare organisation), concentrate on a specific area (*e.g.*, treatment of a specific disease, disaster relief) and be accompanied by an intensive, multicentre simulation (*e.g.*, von Lubitz *et al*., 2004 and in preparation) that would allow realistic testing of all measures involved in complex NHCO and would also define the critical parameters needed for real-life implementation of the NHCO concept.

There is no doubt in our minds that the development of large-scale (particularly international) networkcentric healthcare operations will be complex, expensive, and protracted. Apart from the predictable interference caused by bureaucratic struggles for control and influence, national pride, security issues, incompatibility of laws, and a host of other valid and sometimes quite trivial 'confounders' will play a significant and quite frustrating role. However, the obvious question is not 'how' but 'who will pay for it?' We believe that the incentive already exists. Globally, healthcare already costs trillions of dollars. The rapid increase in population density and age will increase the expenditure even further, and it is already clear that the world's economies will not be able to sustain such a burden. Most likely, the first victims of the inevitable reduction of global healthcare spending will be those who are already struggling desperately merely to afford healthcare at its minimum level. The fragile economies will again begin to falter, tensions will increase, new wars will be fought and, unless timely and effective intervention takes place, the grim 'circle of evil' described by Barnett (2004) will start rolling again. It is thus in the best interest of the world, and particularly in the best, even if selfish, interest of the Western world, to initiate as soon as possible efforts to avert the impending disaster. The burden of turmoil within Barnett's non-integrating gap is already felt by the developed nations. Since the lack of healthcare has been repetitively shown to be significantly tied to the poor performance of local economies, and the latter to the regional lack of stability, self-preservation instincts dictate that the Western governments embark on consistent global healthcare policies that may draw on novel uses of technology generated and tested within healthcare-unrelated domains (including the military). Ultimately, the payer of the forthcoming bill will have the greatest incentive to reduce its estimated future cost – and with the ageing populations and the huge projected costs of supporting them, the Western governments will become the most significant payers.

The existing evidence from military applications and from the still limited e-business experience indicates the soundness of networkcentric philosophy and the practical usefulness of the doctrine. In view of the already staggering costs of healthcare and continuing deficiencies of its delivery, the need for transformation is more than evident. We believe that networkcentric healthcare offers the most tangible and obtainable means of such transformation, and that every effort should be made to pursue the tenets of the doctrine as the platform for changing the face of the global healthcare.

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Note

1 The Honourable Spratt J.M., House Budget Committee, Democratic Caucus: Administration confirms its plan to cut many services deeply in 2006, Washington, DC, 2005 (accessible at www.house.gov/budget_democrats).