11th ICCRTS
Coalition Command and Control in the Networked Era

Title:

A network perspective on organisations: Mapping enterprise C2 networks with MINERVA

Topics:

C2 Concepts and Organisations, C2 Analysis, C2 Modelling, Social Domain Issues

Authors:

Sean Bergin
Effects-Based Modelling and Analysis Group
Command and Control Division
Defence Science and Technology Organisation (DSTO)
Australian Government, Department of Defence,
PO Box 1500, Edinburgh,
South Australia, 5111
Sean.bergin@dsto.defence.gov.au

Rebecca Heyer
Command Process Integration and Analysis Group
Command and Control Division
Defence Science and Technology Organisation (DSTO)
Australian Government, Department of Defence,
PO Box 1500, Edinburgh,
South Australia, 5111
Rebecca.heyer@dsto.defence.gov.au

Christina Stothard
Land Operations Division
Defence Science and Technology Organisation (DSTO)
Australian Government, Department of Defence,
PO Box 1500, Edinburgh,
South Australia, 5111

Alex Flint
Swordfish Computing
C/O Land Operations Division
Defence Science and Technology Organisation (DSTO)
Australian Government, Department of Defence,
PO Box 1500, Edinburgh,
South Australia, 5111

Robin Nicholson
Land Operations Division
Defence Science and Technology Organisation (DSTO)
Australian Government, Department of Defence,
PO Box 1500, Edinburgh,
South Australia, 5111

A network perspective on organisations: Mapping enterprise C2 networks with MINERVA

Abstract

Organisational systems can be represented as networks of ties between the elements of an enterprise. Many ties are prescribed, but many important ties are informal ones initiated and maintained by individuals rather than dictated by executive decree. Informal networks often constitute personal ties that facilitate trading of mutual favours and advice, or 'work around' ties that represent how work really gets done. In dynamic environments formal representations of organisational hierarchies and processes can quickly become out of date, and informal networks are likely to be invisible to commanders and management. Efficient and timely collection of information about the key linkages in an organisation is a significant challenge that needs to be overcome to allow decision makers to see 'the way their enterprise really works'. The present paper discusses the importance of an understanding of the various networks that underlie the functioning of modern organisations, and introduces *MINERVA*, a computer based tool developed by the Defence Science and Technology Organisation (DSTO) for the collection of social and organisational network data. Such data can be used to provide rich and timely representations of command, control, communication and collaboration networks, and generate a common picture of key links and risks in information and resource flows within the system.

Introduction

The present paper discusses the significance of a social perspective on networked organisational systems. We discuss the distinction between formal and informal social networks, their relationship to organisational outcomes, and their relationship to different organisational contexts and fundamental images of the way organisations work. We conclude with a brief overview of MINERVA, a computer application developed by Australia's Defence Science and Technology Organisation (DSTO) for the collection of social and organisational network data that can provide rich and timely representations of the key relationships between elements of organisational systems.

A network view of organisations

Few would deny that humans are social creatures. Anywhere that there is more than a handful of people in the world we find them interacting in interlinked social systems to achieve outcomes that the individual members could not achieve on their own. Sometimes the primary motivation for members of such systems is their own individual desires (e.g. getting paid); in other cases the system might be associated with some collective identity, with its own superordinate goals that members subscribe to and seek to fulfil.

One might draw a distinction between social *groups* or *collectives* on the one hand, and *organisations* or *enterprises* on the other. In many social groups membership may simply be associated with some common characteristic (e.g. support for football club or co-habitation in the same village). Organisations, however, are characterised by being not only social systems, but also 1) goal directed and 2) deliberately structured and co-ordinated activity systems (Daft, 2001). As such, organisations entail a high degree of interdependence, cooperation and shared goals between members. Given that organisations have goals (however fuzzy these may sometimes be), leaders and members need ways of understanding their organisation in order to ensure that the organisation is best able to achieve these goals.

One approach to understanding social and organisational systems that has become increasingly popular in recent times is the network approach to organisations. In the network perspective, organisational systems can be represented as networks of ties of reporting, communication, collaboration and resource flows between the elements of an enterprise. This sort of analysis contrasts with the more typical approaches to understanding social systems that focus on the *characteristics* of entities, by focusing on the *relationships* between elements of the systems.

Arguably, the network approach is not really new. A hierarchy is a fairly ubiquitous form of network in social systems that humans have long recognised and embraced for provision of control and co-ordination. The engineering oriented approaches of business process mapping also are a form of network analysis in which the links are the prescribed collaborative and exchange relationships between elements of the organisation. The recognition of the importance of information flow in light of the advent of cheap and fast modern communication networks, however, has spawned a new interest in thinking about the significance of network structures.

In the military world, this interest has given rise to concepts of Network Centric Warfare (NCW), which focus on the technological aspects of linking actors in the battlespace to distant and distributed sources of information as required. However, as well as the recognition of the importance of electronic linkage and transfer of explicit[1] information, research over the past few decades has provided irrefutable evidence of the importance of the more human aspects of organisational ties, supporting the notion that "it is not just what you know, but who you know" that is important.

Person-to-person links may represent formal processes, or additional channels through which explicit knowledge is transferred. However, even though such links may be highly prescribed, one must realise that they are still fundamentally *social* ties. People are not passive transmitters and routers of data or resources, akin to machines on a conveyer belt, or nodes in a computer network. Rather, they are influenced in their behaviour with others by how they feel about the people they are interacting with.

---

[1] *Explicit* information is the sort of information that that can be written down or structured unambiguously, or that can be abstracted with little loss of meaning. This is the sort of information that can be easily stored, located, and transmitted electronically, and which may lend itself to being 'machine readable'.

Furthermore, much of the knowledge in organisations is rich, complex or tacit[2] knowledge that is difficult to impart in an explicit form, and hence to store and transmit electronically (Swan, Newell, Scarborough & Hislop, 1999). Such knowledge is often tapped on an ad hoc basis through advice from experienced people, or diffused in a less conscious way through other social learning mechanisms. Often the more efficient (or indeed the only possible way) to transfer such knowledge effectively is through social networks.

The structure and nature of social networks provides constraints and opportunities in relation to access to resources within the organisational system. Access to information resources constitutes a form of intellectual capital that contributes to an organisation's overall value as much as the assets and human resources that it possesses. Indeed recent approaches in the corporate sector have explicitly realised this and explored ways of factoring this into an organisation's monetary valuation (e.g. Lock Lee, 2000). The importance of the social networks representing person-person ties is also clearly acknowledged in numerous doctrinal and higher level military concepts references in the Australian Defence Force (ADF) (i.e. *Force 2020,* (Australian Deparment of Defence, 2003) and *Future Warfighting Concept* (Australian Department of Defence, 2003) as well as rapidly growing bodies of knowledge relevant to military, organisational and management sciences (e.g. Atkinson & Moffat, 2005; Cross and Parker, 2004; Jones, Conway and Steward, 2001; Kilduff & Tsai, 2003; Nohria & Eccles, 1992; Stacey; 1996; Tsoukas & Mylonopoulos, 2004).

Formal and informal networks in organisations

Morgan (1997) in his book *Images of Organisations* makes the case that our views of organisations are shaped by the underlying metaphorical images we have of them. What we perceive to be important components and outcomes of the systems, and how we conceive the relationships between them, is not objective, but is guided by these underlying metaphorical images of 'what organisations are like'. The various metaphors highlight some aspects of organisations while downplaying others.

Mechanistic images of organisations: formal networks

One view that Morgan discusses is a *mechanistic* view of organisations. Mechanistic approaches view the organisation as having a specific known and objective function to achieve. The focus for organisational design from the mechanistic viewpoint is on how to achieve this function with the greatest efficiency and stability. Design is seen as an internally focused, technical problem. The system is seen to have some optimal state which one should aim for. Change ideally occurs through formal feedback mechanisms, analysis and optimisation by some central executive, and top down reengineering of the system to reach a state closer to the optimum. Organisational design tends to be seen as a 'noun' – a static representation of the components of the system, and the structure of the relationships between them. The focus is on *formal* or *prescribed* processes (such as reporting chains and standard procedures) mandated by some authority, and designed on the basis of engineering principles.

---

[2] *Tacit* knowledge is complex knowledge that people often do not even know they possess. It gets transmitted through stories about experiences, or through dialogue between multiple parties, and is often impossible to encode explicitly.

Morgan notes that these principles are so pervasive in management today that the pattern is often described as 'McDonaldisation', where emphasis is on separation of design and execution of tasks, efficiency, quantification, predictability, control and deskilling of jobs. Systematic and scientific analyses of the formal processes in an organisation can (as thousands of McDonalds franchise owners around the world would agree) lead to enduring high levels of performance for organisations, and are common in the design of military systems and in operations research. However, as Morgan points out, an image is only useful to the extent that the metaphor 'fits' the system to which it is applied. Mechanistic approaches work when the organisation *is* like a machine, but the usefulness of the image in the past should not blind us to recognising that *not all organisations are* like machines.

Living images of organisations: informal networks

In complex and dynamic work contexts it is often difficult to 'design' work processes in the sense that McDonalds restaurants can design the organisation of a franchise. Standard Operating Procedures are difficult to create, since it is difficult to identity what constitutes a 'standard' situation in the first place. Such contexts are the domain of alternate images of organisations such as an *organic* image of organisations (Stevenson, 2001), Senge's (1991) *learning organisation*, and the organisation as a *brain (*Morgan, 1997). These sorts of images might collectively be referred to as *living* images of organisations.

In such contexts, 'knowledge work' rather than 'process work' becomes the core activity, and formal processes can often not be realistically expected to be identified and prescribed in advance. The tasks that people really need to undertake, and the ties that people will need to utilise are not often predictable in advance. Rather, the activities and linkages evolve depending on the problem a person is faced with, and that person's current knowledge of where they can go to get relevant information. Additionally, while explicit knowledge is still important in these contexts, tacit knowledge (and its transfer) becomes much more salient in relation to organisational outcomes.

Even for supposedly predictable and routine situations, many prescribed processes that seem sensible in principle are often found to be destructive or impossible to implement in practice. In such environments, where people are faced with either no direction or impracticable directions as to what they are 'supposed to do' people will generally use their initiative to work around procedures, or voluntarily make informal links that they perceive to be useful to achieving work outcomes.

The *shadow organisation* (Stacey, 2001) is a useful term that highlights these hidden networks. The shadow organisation is the set of dependency networks that constitutes that way the organisation *actually* functions. These networks are rarely recognised in official representations of an organisation, and may be found in informal networks such as smokers networks, advice networks, 'old boys networks', and so on. While the shadow organisation may be supported by formal mechanisms such as official collaborations or liaison roles, these are rarely shown in formal diagrams of an organisation's structure or processes. A large body of research has consistently shown that informal networks can have significant effects on important outcomes at the individual and organisational levels (e.g. Cross & Parker, 2004,); Cross, Parker &

Sasson, 2003; Kilduff & Tsai, 2003; Lin, Cook & Burt, 2001; Nohria & Eccles, 1992; Wasserman & Faust, 1994).

The dependency of organisational outcomes on informal structures, and the potential for both alignment, and misalignment, between organisational goals and informal networks is an important issue. Whilst some informal networks in organisations may be more a result of affective choices (e.g. friendships), it would be a mistake to assume they simply represent a 'sociable' network independent of organisational goals. Many informal work ties are likely to have little affective motivation, but rather be quite deliberate, goal oriented structures that people evolve simply to get their work done in the best way they know how. This can contribute greatly to organisational performance. On the other hand, if members of the organisation perceive the formal structures to be repressive or misguided, the individual's definition of their goals may shift against the organisation's, (or at least management's perception of the organisational goals) and the informal networks can form the infrastructure for rebellion against the ruling regime. This is another important argument for understanding the informal network structures in play in an organisational setting, to see where the informal networks are aligned with organisational goals, and where there is current or potential conflict between the formal and informal structures.

A synthesised view: multiplex, multimodal networks

Mechanistic approaches, with their focus on *formal* or *prescribed* structures, invariably ignore the significance of informal or ad-hoc networks. In situations in which the organisation *is* like a machine, foci on formal aspects of the system may be sufficient to explain the majority of organisational outcomes of interest. However, in more complex organisational environments a representation of an organisation through a mechanistic perspective may only target a small proportion of the important components and relationships. In these cases, a living image may be more suitable, with its recognition of the role of emergent informal networks and the conscious agency of group members in interpreting and actively seeking to achieve outcomes that benefit the organisation.

The authors note that the importance of informal network structures does not mean that one should ignore the significance of formal structures. It is the author's contention that the real goal is not to take one side or the other (i.e. formal versus informal), but rather to account for *any* type of network that has a significant effect on key aspects of organisational performance. This is undoubtedly context dependent, and will likely include *both* formal and informal networks to some degree. This synthesised view is what we might term a *multiplex network view* of organisations (Monge & Contractor, 2003).

We further note that although we have focused this discussion on human to human networks, a comprehensive analysis of an organisation is likely to require a broader view of what constitutes an organisational network. This would likely include not only person to person links, but also links between a range of other types of nodes, such as tasks or resources. Networks with different node types are referred to as *multimodal* networks (Monge & Contractor, 2003).

Social Network Analysis

We have argued that both formal and informal links are important to organisational outcomes. But how can detailed knowledge of such networks in a specific context actually help us as leaders, managers, or members of such systems? One answer lies in a growing field of research known as Organisational or Social Network Analysis (ONA/SNA[3]). SNA is a field of research that provides a set of tools and theoretical approaches for holistic exploration of the communication and interaction patterns of social systems. SNA draws from many disciplines including sociological and psychological network theory, organisational behaviour, complex adaptive systems, and a branch of mathematics called graph theory.

SNA research maintains that the advantage of a network approach is not simply that one sees links that one may otherwise have missed, but rather that a knowledge of how all these individual links *fit together* into local and global structures can provide invaluable additional insights.

SNA approaches have been validated in many settings with numerous authors demonstrating the insights that can be gained through understanding social and organisational systems from a network perspective and the gains that can be achieved through explicitly harnessing these insights to achieve organisational outcomes (e.g. Borgatti and Cross, 2003; Cross, Parker & Sasson, 2003; Cross & Parker, 2004; Jones, Conway & Steward, 2001; Kilduff & Tsai, 2003; Lin, Cook, & Burt, 2001; Monge & Contractor, 2003; Tichy, 1981; Tsoukas & Mylonopoulos, 2004; Wasserman & Faust, 1994; and Wasserman & Galaskiewicz, 1994). Some of the areas that might be of interest within a military environment include information flow, innovation, common awareness, decision outcomes and quality, satisfaction, promotion, influence, power, control, cohesion, and cultural evolution.

Typical SNA studies

Typical SNA studies identify the sorts of 'nodes' and 'links' that are thought to be related to phenomena of interest, and collect data about these in a target population. Nodes might be people or groups, or they might be other types of things such as events, task, or resources. Ties are any sort of relationship that binds the nodes. These might include (but are not limited to) reporting, friendship, collaboration, or advice between people; attendance between people and events; ties between people and tasks; or ties between people and the resources they require for their work. A *global* network map is then typically created that can reveal the 'real' structure of the system.

At the very least this can provide an advantage by providing an *up-to-date* map of key formal structures and processes across an enterprise. Such representations are often not available in organisational settings characterised by rapidly changing or highly interconnected structures, and consequent out-of-date and incomplete representations of C2 structures.

---

[3]**Although the two terms are often used interchangeably in the literature, SNA tends to focus on theory and analysis methods related to people and groups in a large range of social settings, whereas ONA tends to have a wider scope of node types focused within a more formal organisational setting. For consistency, we shall use the more widely used term SNA in the remainder of the document, but intend this to encompass the body and philosophy of ONA research as well.**

The real value of a network approach, however, is achieved by conducting various forms of analysis based on SNA theory and methods. Analysis might be as simple as feeding back the network map to the target community and using it as a focal point for discussion. For example, a social network map might reveal several large clusters of people with little communication between groups; a pattern that might be indicative of a block to cultural integration. Such analyses can provide insights to group members by combining their rich contextual knowledge of the system and intuition with a network perspective that provides a more holistic view of the connections within the system; in effect, helping people see the 'forest' as opposed to the 'trees'. Alternatively more formal quantitative analysis can be undertaken to identify parts of the network that exhibit particular structural characteristics.

For example, at the individual level, one might identify the most *central* nodes (Freeman, 1979) in the network on the basis of how many connections they have (*degree centrality*), how many 'steps' they are away from everyone else (*closeness centrality*), or the extent to which a node forms a bridge between disconnected parts of the network (*betweenness centrality*). Alternatively, one might apply computational algorithms to explore more global patterns around nodes by looking for nodes that occupy *structural holes* in the network (Burt, 1992). At a more global level one may seek to identify nodes with *structural similarity* or *equivalence* (e.g. Burt, 1976; Breiger, Boorman, and Arabie, 1975) in their surrounding network structure; *cutpoints* or *keyplayers* (Borgatti, 2003) that may cause the network to fragment if they were removed; or perhaps higher level *emergent groups* that reflect clusters of highly connected nodes (e.g. Luce and Perry's (1946) concept of cliques).

Interpreting measures

Once quantitative network measures have been assessed, they can then be interpreted in light of relevant social theory to tell us something about possible behaviours of elements of the network.

For example, people high in *degree* centrality might be relatively critical to functioning of the organisation, and might have a high degree of influence. On the other hand they might also be overloaded, and risk becoming bottlenecks in the network. High *closeness* centrality might indicate that a node is likely to be well informed about what is going on in the organisation, since information is likely to reach them faster and in a less distorted form than it will reach others who are more on the periphery of the organisation. High *betweenness* might indicate a form of power, since a person who links disconnected nodes can recognise and broker between the needs and resources of others.

The extent to which a node occupies a *structural hole* is suggestive of the level of freedom and power a person wields in their local network by being well connected to a local network of disconnected contacts. Those who occupy a structural hole are likely to 1) have many non-redundant contacts, and thus access to a range of resources from other nodes, 2) not be constrained in their own behaviour by their contacts, since their contacts are independent of each other and thus less likely to exert normative influence upon them, and 3) have opportunities to profit from brokerage between contacts, since they know the needs and resources of people who are disconnected, and can broker possible exchanges that would otherwise not likely be realised.

Structural similarity between nodes might reveal particular roles that might be invisible to the formal view of the organisation. For example, a number of people who may not talk to each other, but who occupy a similar structural position in that they form an important link between two distinct groupings (e.g. old employees and new employees). Identification of important structural roles like this can help management recognise important functions that have emerged in the system, and potentially make changes to the formal systems to support and protect these functions.

Cutpoints and Borgatti's *Keyplayers* are nodes whose removal would fragment the network into disconnected subgroups. These might represent key people that hold the social network together and who need to be protected to minimise the risk of the network fragmenting.

Emergent groups can provide some of the most important insights at the more global network level. Generally, when one thinks of groups in an organisation, one defines them by some nominal label, such as their function (e.g. finance, or planning), or administrative grouping (e.g. Branch/Section/Unit). While networks may be entrained around such formal labels and groupings, (Robins, Pattison, Rogers, & Bergin, 2006), networks can, and often do, span the divide. The concept of a group from a network perspective is more about the degree to which people are actually connected than any shared characteristic or label imposed from the top down. Emergent groups form on the basis of actual interaction patterns, and reflect the groups that really exist rather than the often artificial boundaries of formal organisational charts. Recognition of emergent group structure can highlight where collaboration and information sharing is occurring, and where it is not.

The degree to which groups overlap or are connected to each other can be an indicator of shared awareness, positive affect, and collaboration between groups. The degree to which emergent groups are disconnected can be a strong indicator of where gaps in communication lie, and the potential for disparate views and even conflict. It can also be an indicator of possible inefficiency and ineffectiveness, and the gap may represent a chasm to social learning. Lessons learned by one group may not be transmitted to the other and the same errors repeated by the different groups. Additionally, both groups may be spending resources on the same types of activities, and losing the synergistic benefits of joint efforts.

These concepts are only a few of the possible areas that can be explored with formal methods of SNA/ONA. Due to space limitations we cannot discuss the full range of possibilities in detail in the present paper, and the ones we have discussed have been presented simplistically. For the interested reader, there are a number of excellent detailed introductions to analysis of social networks, (e.g. Cross & Parker, 2004; de Nooy, Mrvar & Batagelj, 2004; Monge & Contractor, 2003; Scott, 1992; Wasserman & Faust, 1994). Even this brief discussion however, highlights some of the insights that a network approach can provide that would be invisible to more traditional methods of organisational analysis.

MINERVA

We have argued that a holistic view of the multiplex networks that support organisational function is a valuable aid in understanding organisations and helping

guide decisions about organisational design and development. We have also argued that formal representations of organisations as embodied in org charts and process diagrams are often insufficient for understanding the real structure of organisations, because they are 1) often out of date and 2) fail to capture the informal networks that may play a critical role in the way an organisation functions. Other forms of archival network data exist, such as email and phone records, but while they may be indicative of a more complete network of communication, their lack of richness means it is difficult to interpret the meaning of emergent structures at anything other than a high level of abstraction.

The richest data collection methodology for SNA is the collection of self-report data. Common methods include paper-and-pen surveys, interviews and observations. Data collection involves getting respondents (the 'ego') to provide some information about themselves, as well as getting them to nominate their contacts ('alters'), and information about the tie they have with each named contact. In some cases, data is also collected about attributes of the alters. Such methods tend to be resource intensive, are plagued by low response rates (and consequent missing data), and pose challenges for researchers in terms of synthesis and manipulation of data.

Whilst computer based administration of instruments can have significant advantages, tailor made design and programming of such instruments for specific projects is resource intensive (not to mention inefficient), and beyond the cost and timeframe constraints of many projects[4]. In response to a need for an easy to use, flexible, and reusable capability for survey creation and administration, researchers at the Defence Science and Technology Organisation have developed MINERVA[5], a web based application for the creation and administration of social/organisational network surveys.

Potential applications which MINERVA may support.

MINERVA is fundamentally a data capture tool, not an analysis tool in itself. However, unlike the majority of comparative survey tools available, MINERVA is uniquely designed to enable collection of organisational *network* data that may then be used in a variety of ways to improve organisational performance. A number of initial possible applications were used as guides in the initial development of MINERVA. These included:

Overcoming limitations of formal and/or outdated organisational representations

MINERVA could be used to capture important formal and informal organisational links at the individual or group level, and create a synthesised enterprise level view of organisational structure. This can provide a valuable management aid to overcome the limitations of incomplete or out-of-date formal representations in dynamic environments. It is particularly useful for relatively transient organisational structures such as task forces, teams, and coalitions.

---

[4] **Recently several commercial tools have appeared that are intended to provide researchers with the ability to conduct customised SNA questionnaires. These include IKNOW (Contractor, O'Keefe, and Jones, 1997) and Egonet (McCarty et al 2003). Unfortunately these tools both had limitations to the degree of customisation that was possible, and hence the capability to meet the needs of many of the sorts of projects envisages by the authors.**
[5] **MINERVA is named after the Greek goddess of weaving.**

Risk identification

Analysis of organisational networks captured with MINERVA can help to identify key links and nodes (including people, tasks, resources) in the organisational network, and possible weak points in the system.

Optimising physical layout of personnel

Physical distance between members of an organisational system can have a powerful effect on performance. Knowledge of key ties and associated indicators of requirements for physical proximity between actors can help to guide decisions about physical placement of staff in a new facility.

Testing formal processes

MINERVA could be used to test formal organisational structures by running hypothetical experiments to see what parts of an organisation would be 'activated' and how long the organisation would take to react in the face of a given event (e.g. what would happen if person 'x' found out about a non-responsive aeroplane heading toward the capital city; who would they contact, and what resources would they need; who would their contacts contact, and what would they need, and so on).

Rapid Role Profiling

MINERVA could be used to undertake 'rapid role profiling' for positions to aid in minimising the negative effects of the posting cycle. This would be achieved by getting outgoing billets to provide a map of the key formal and informal contacts and resources that they have found beneficial to their work activities, and providing this map to new billets to bootstrap their integration in the new position.

360 degree evaluation

MINERVA has the potential to be used for 360 degree feedback incorporating the full spectrum of formal and informal organisationally related ties that a person is engaged in.

Pure research to guide development of organisational models

While much research has been undertaken on the characteristics and dynamics of networked social systems, the majority of this research has been undertaken in corporate and civilian environments. There is a need for further research to empirically explore the way networks behave in military organisations to inform the development and validation of simulation models for such organisations. MINERVA provides an efficient capability for data collection to support this.

Summary of functions and features

Intuitive design

Survey design is achieved through an intuitive interface designed to be usable by those with no programming knowledge. Administration is conducted via the WWW or through an intranet, and respondents can access the survey using a standard web browser.

Flexibility

MINERVA allows collection of quantitative and qualitative data on both *nodes* and *ties* within a population, and is highly flexible in terms of presentation of questions. MINERVA can incorporate numerous types of variables including 1) dichotomous (binary) variables, 2) multiple choice questions, 3) ordinal or continuous scales, or 4) free text responses. Questions can be posed 'by alter' (i.e. a series of questions are presented for each contact in turn) or 'by question' (i.e. each question is posed for all alters before moving to the next question).

Dynamic reporting of survey statistics

MINERVA maintains a number of details in relation to ongoing survey administration. These include 1) the number of people who have responded so far together with a list of names and time-stamped records for all respondents in relation to login, informed consent, and response time, and 2) a running value for maximum, minimum and average time taken to complete survey.

Support for snowball sampling

MINERVA provides a dynamically updated list of named contacts who have been nominated but have not responded to the survey, together with a report on the number of times the contact has been nominated. This allows for a dynamic 'snowball' method of identifying further individuals that should be targeted as respondents, which is particularly useful in ill-defined populations.

Useable in various populations

MINERVA can be used with small or very large populations, and can be used in populations that are predefined or partially or completely undefined. In defined or partially defined populations, MINERVA uses an underlying *organisational architecture* (based on formal organisational contact lists) to initially provide users with a searchable list of contacts that can be filtered on the basis of contact attributes. The architecture can be automatically generated from comma separated text files or Microsoft Excel sheets with information about names, and organisational affiliations (e.g. name/branch/Section/unit etc.). MINERVA also incorporates the ability to add contacts to the underlying database on an ongoing basis if the respondent has a contact that is not included in the underlying architecture. This method reduces time and effort on behalf of the respondent, reduces possible bias by prompting users to consider contacts from a full range of potential groupings, resolves aliasing problems, and allows for ongoing validation of contact details.

Accordance with established ethical aspects of data collection

MINERVA was designed in accordance with nationally established ethical guidelines for social research in defence, as well as recently recognised issues specific to social network research (e.g. Borgatti and Molina, 2003, 2005; ADFP P.1.2.5.3 - *Health and Human Performance Research in Defence – Manual for Researchers*). The tool includes a formal introduction and welcome page that can be modified by the survey designer, as well as a consent page with the facility to collect time-stamped consent from respondents.

MINERVA allows for a distinction between *public* and *private* data. Public data is the sort of data that respondents can reasonably be expected to share with others, such as

formal reporting or collaboration structures. Private data is information that may be considered sensitive at the individual level, for example, positive or negative perceptions of people that may imply judgement of others. The distinction is clearly indicated to participants at the time of response, allowing a greater potential for providing useful feedback of useful 'public' information to a wide community, while promoting validity for more sensitive information that will not be ascribed to individuals. MINERVA comes with a template for ethics considerations based on Australian ethical guidelines but allows for modification in light of international variations in requirements.

Incorporation of Touchgraph network visualisation for respondents

MINERVA incorporates the third party application *Touchgraph* so that participants can benefit from visualisation of the public network data upon completion of the survey.

Automatic data export

MINERVA automatically combines individual 'egocentric' network data into a global network dataset. MINERVA can export complete or partial amalgamations of the dataset into standard CSV or excel files for analysis in other visualisation or analysis packages. MINERVA also exports complete or partial datasets to formats suitable for use in the well known networks visualisation and analysis package *Pajek* (Batagelj and Mrvar, 1998).

Current Status

MINERVA is currently in advanced beta testing, and is expected to be ready for wider use by the end of 2006. Beta versions may be made available through negotiation with the authors.

Conclusions

In the words of John Arquilla and David Ronfeldt from RAND "w*hoever masters the network form first will gain major advantages*" (Arquilla & Ronfeldt, 2001, p.15). Understanding that the 'network form' is more than just the electronic links, but also the human linkages is a key insight. However, *recognition* of this insight is only the first step of mastering the network form. Understanding *how to use* the insight to achieve the adaptive, robust, and effective networked organisation of the future will require a significant investment. Our argument so far leaves us with a number of insights in relation to social networks in military organisations.

Firstly, the structure of social/organisational networks provides constraints and opportunities to individual 'nodes' in the network, depending on their state of 'embeddedness'. The nature of this structural landscape (rather than simply internal attributes of nodes) can have a wide range of effects on effectiveness and performance at the individual, group, and organisational levels.

Secondly, it is critical to consider *informal* networks as well as *formal* ones in relation to organisational outcomes. Informal structures, however, are often quite unrelated to formal design of the organisation as envisaged by management, and are likely to either be unrecognised or ignored as salient factors in organisational outcomes. The

traditional focus on formal structures as epitomised by Business Processes Reengineering (BPR) and formal process modelling approaches is doomed to only ever see a small part of the picture. However, the growing body of research in the area demonstrates the significant competitive advantages that can be gained by taking informal structures into account.

The implications of this are significant for development of C2 systems – successful command and control needs to acknowledge that the informal systems have a powerful affect on outcomes, but also that they are a two edged sword. If ignored or left to 'chance' they may support the formal structures, but they may equally work in conflict with the prescribed system. Alternatively, as is being realised in many corporate settings, if they are deliberately cultured and supported, they can provide significant beneficial outcomes. This does not imply that informal networks are the only things that are important, or that one should seek to do away with or ignore formal structures and hierarchies. Rather, one should consider the complete *multiplex* network in organisational systems, including both formal *and* informal networks in thinking about what it means to be a networked organisation. The ultimate goal is to achieve the right balance between formal and informal structures, to gain the advantages of efficiency and control accorded by formal structures, as well as the adaptability, effectiveness and learning capacity of organisationally aligned informal structures.

Thirdly, while not yet mainstream, formal analysis methods developed in the SNA field provide us with the ability to go beyond simply mapping structures in networks, and conducting mechanistic simulations of formal processes. With SNA approaches we are able to draw theoretically grounded inferences and insights about organisations that account for important *social* aspects of organisations, and can simultaneously account for macro levels outcomes while retaining richness of individual level characteristics. These sorts of insights are unachievable through traditional mechanistic approaches to organisational design and evaluation.

In military contexts, social network approaches are relevant in a number of ways. Firstly, they can help commanders, managers, and members of the organisation get a clear and up to date representation of the key formal and informal dependencies in their organisation. Secondly, the recognition of informal processes can highlight critical connections that would remain invisible if one relied on formal representations of the organisations. Thirdly, network approaches can reveal key aspects of the structure at the individual and macros levels, particularly with respect to weak points in the system that make the organisation vulnerable to damage, or emergent group structures that might reveal collaboration and information diffusion patterns. Fourthly, studies on military organisations can provide valuable empirical support for development of modelling and simulation capabilities for military organisational systems.

SNA approaches come to the fore in organisational systems which are characterised by: unstable environments; being highly influenced by informal communication and collaboration structures; facing complex and unpredictable problems; the predominance of 'knowledge work', rather than manual labour in the workforce; and a focus on decisions rather than 'products' as the primary output. The above characteristics are not just variable individual differences observable in organisations,

but rather representative of organisational trends in the workforce as a whole in the contemporary Western world. As such, these approaches are likely to gather more and more momentum and significance in organisational design.

MINERVA provides a much needed step in the development of capability for collection of data about networked social and organisational systems. It should be noted, however, that the focus of MINERVA is the *technical* side of survey creation and administration. MINERVA is designed to be flexible enough to incorporate a wide range of survey content; however, survey content is an altogether different (and challenging) task, which needs to be carefully undertaken on the basis of the specific needs of individual SNA projects. Additionally, MINERVA is a data *capture* tool, and while it has limited visualisation capabilities, it provides little in the way of flexible analytic capabilities. The specific application of the network data in a given case will dictate the necessary additional tools and expertise required to succeed. However, MINERVA has been designed to be able to export directly to formats readable by both traditional statistical analysis tools, as well as commonly used SNA tools such as Pajek (Batagelj & Mrvar, 1998) and UCInet (Borgatti, Everett & Freeman, 2002).

While a number of possible applications have been proposed that have guided the development of MINERVA, further research will be needed, to validate and refine these in terms of appropriate survey content and analysis methods. More generally, mastering the network form will require a significant investment in pure research to understand and anticipate the behaviour of the 'softer' social aspects of military organisational networks, and to further identify possible applications of this type of research to promote better organisational performance.

The scientific understanding of social networks is rapidly increasing, but we will need to ensure further work specifically aimed in military contexts is supported in order to realise maximum benefits from these developments. At the present the vast majority of the billions of dollars of resources expended to achieve 'the network advantage' are focused on purely technological outcomes. Work on the social aspects of networks in military organisations, on the other hand, is limited to a handful of researchers around the world. Hopefully, this imbalance in investment will be adjusted in the future as we come to realise the impact that informal networks have in military enterprises. If this is not the case, no matter how superior our technology is, we may find ourselves at a disadvantage against enemies who do master the social side of the networked organisational form.

References

ADDP–D.2 (2003). *Force 2020*. Department of Defence, Canberra.

ADDP–D.3 (2003). *Future Warfighting Concept*. Department of Defence, Canberra.

ADFP-P.1.2.5.3 (XXXX). *Health and human performance research in defence – manual for researchers.* Department of Defence, Canberra.

Atkinson, S. R. and Moffat, J. (2005). The agile organization: from informal networks to complex effects and agility. Washington, D.C. CCRP.

Arquilla, J., & Ronfeldt, D. (2001). *Networks and Netwars*. Santa Monica: RAND Corporation.

Batagelj V., Mrvar A. (1998). Pajek - a program for large network analysis. Connections, 21 (2), 47-57

Borgatti, S., Everett, M. & Freeman L. (2002) *UCINet 6 Network Analysis Software*. Analytic Technologies. Harvard. MA

Borgatti, S.P. (2003). The Key Player Problem. in *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers,* Breiger, R., Carley, K. & Pattison, P. (Eds.), National Academy of Sciences Press.

Borgatti, S.P. and Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science. 49(4)*: 432-445.

Borgatti, S.P. and Molina, J-L. (2005). Toward ethical guidelines for network research in organizations. *Social Networks, 27(2):* 107-117

Borgatti, S.P. and Molina, J-L. (2003). Ethical and strategic issues in organizational network analysis. *Journal of Applied Behavioral Science. 39(3):* 337-349.

Breiger, R., Boorman. S. and Arabie, P. (1975). An algorithm for clustering relational data, with applications to social network analysis and comparison with multi-dimensional scaling. *Journal of Mathematical Psychology, 12*, 328-383.

Burt R (1976). Positions in Networks. *Social Forces, 55*, 93-122.

Burt, R.S. (1992). *Structural Holes: The social structure of competition*. Cambridge: Harvard University Press.

Contractor, N. S., O'Keefe, B. J., & Jones, P. M. (1997). *IKNOW: Inquiring Knowledge Networks On the Web.* Computer software. University of Illinois.

Cross, R., & Parker, A. (2004). *The hidden power of social networks: Understanding how work really gets done in organizations.* Boston: Harvard Business School Press.

Cross, R., Parker, A. & Sasson, L. (Eds). (2003). *Networks in the knowledge economy*. New York: Oxford University Press.

Daft, R.L. (2001). *Organization Theory and Design (7th Edition)*. Cincinnati, OH: South-Western Publishing.

de Nooy, W., Mrvar, A. and Batagelj, V. (2004). *Exploratory Social Network Analysis with Pajek*. NY. Cambridge University Press.

Freeman, L. C. (1979). 'Centrality in Social Networks: Conceptual clarification', *Social Networks 1*, 215-239.

Golembiewski, R.T. (Ed) (2001). *Handbook of Organizational Behavior (Second Edition).* New York: Marcel Dekker.

Jones, O., Conway, S. & Steward, F. (Eds). (2001). *Social Interaction and Organisational Change: Aston Perspectives on Innovation Networks.* London. Imperial College Press.

Kilduff M. & Tsai, W. (2003). *Social Networks and Organisations.* London: Sage.

Lin, N., Cook, K. and Burt, R. (Eds). (2001). Social capital: theory and research. Chigago, IL. Aldine de Gruyter.

Lock Lee, L. (2000). Knowledge sharing metrics for large organizations. In: Maybury, M.,Morey, D. & Thuraisingham, B. (Eds.), *Knowledge Management – Classic and Contemporary Works. Cambridge,* MA: Massachusetts Institute of Technology.

Luce R and Perry A (1949). A method of matrix analysis of group structure. *Psychometrika 14,* 95-116.

McCarty, C. (2003). *Egonet. Personal Network Software.* MDLogix. http://www.mdlogix.com/egonet.htm

Monge, P.R. & Contractor, N.S. (2003). *Theories of communication networks.* New York: Oxford University Press.

Morgan, G. (1997). *Images of Organization.* Thousand Oaks: Sage Publications.

Robins, G., Pattison, P., Rogers, P. & Bergin, S. (2006). *Multiple networks in organisations.* Draft DSTO Technical Report.

Scott, J. (1992). *Social Network Analysis.* Newbury Park, CA. Sage.

Senge, P. (1991). *The Fifth Discipline: The Art and Practice of the Learning Organization.* New York: Doubleday.

Stacey, R.D. (2001). *Complexity and creativity in organizations.* San Francisco: Berrett-Koehler.

Stevenson, W.B. (2001). Organization Design. In Golembiewski, R. T. (Ed) (2001). *Handbook of Organizational Behavior (Second Edition).* New York: Marcel Dekker.

Swan, J., Newell S., Scarborough, H. & Hislop D. (1999). Knowledge management and innovation; networks and networking. *Journal of Knowledge Management.* 3(4): 262-275.

Tichy, N. (1981). Networks in organisations. In Nystrom, P.C. & Starbuck, W.H. (1981). *Handbook of organisational design.* Oxford: Oxford University Press.

Tsoukas, H., & Mylonopoulos, N. (2004). *Organizations as knowledge systems: Knowledge, learning and dynamic capabilities.* New York: Palgrave Macmillan.

Wasserman, S., & Faust, K. (1994). *Social network analysis: methods and applications.* Cambridge: Cambridge University Press.

Wasserman, S., & Galaskiewicz, J. (Eds). (1994). *Advances in social network analysis: Research in the social and behavioural sciences.* Thousand Oaks: Sage.