Augmented C2 Assessment Using Digital Data

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Abstract

The adoption of digital systems in Command and Control (C2) organisations presents many opportunities to automate and streamline the assessment of C2. In addition, while digital C2 systems continue to be rapidly deployed and evolved, there is an ongoing challenge in assessing the effect a new digital system or process has on C2 performance. Historically, data for C2 assessment has been gathered directly from humans in the form of observations, interviews and surveys. While measurement of human to human interactions remain key to a well-functioning C2 organisation, the growing importance and wealth of digital data available presents an opportunity to assess C2 in hitherto unexplored ways. By using digital C2 data we can automate and expand the breadth and volume of information gathered for C2 assessment while also collecting data that was previously impractical to gather from human observations. This paper presents a generalised methodology for gathering digital data from C2 systems and applying it in conjunction with human observable data to assess C2 across the entire sociotechnical spectrum. This methodology has been tested on the Australian Defence Force (ADF) operational planning process in the context of an ADF Command Post Exercise (CPX).

1 INTRODUCTION

Command and Control (C2) systems are sociotechnical systems. As such, methods for assessing the performance of C2 organisations should consider the lens of social dynamics as well as how they are expressed in the modern technological systems that are intended to enable the functions of C2. In this paper, we develop an approach for drawing upon the digital footprint of human participants in C2 systems and show how analysis of this can begin to provide insights into the performance of the system and supplement traditional C2 assessment techniques.

To expand on these propositions, we begin with the definitions of Pigeau and McCann [1], where Command is the "creative expression of human will necessary to accomplish a mission", and Control as "structures and processes devised by Command to enable it and manage risk", and C2 [2] as "the achievement of common intent for coordinated action". The human dimension of this is clear, the highlighting of which is central to the Pigeau-McCann framework. In the modern era it is inescapable that the human participants of a C2 organisation typically a military headquarters at some command echelon, must use technological systems to perform the functions of C2. Allard [3], for example, provides a comprehensive overview of such technologies up to the 1990s. Sociotechnical systems theory [4] provides a comprehensive and coherent approach to considerations of these key aspects of C2, particularly in the context of implementation of Network Enabling concepts [5]. Badham et al. [6] specifies five characteristics for sociotechnical systems, with two of importance for our paper (emphasis in italics): such systems have an "internal environment comprising separate but *interdependent* technical and social subsystems", and "their performance relies on the *joint optimisation* of the technical and social subsystems". Failing to do the latter leads to "degraded system performance and utility".

In this paper we focus on the *assessment* of C2: evaluating how an existing C2 system performs its purpose of "exercising control of its environment" [7] through processing of information and decision making across all members of the system with its assigned resources. Within the Measures of Merit framework, we focus on Measures of Performance, meaning the focus on "internal system structure, characteristics and behaviour". Because we illustrate our approach using activities conducted by a headquarters in planning before execution because of the constraints of our data collection at a point in time; to that end we do not venture into Measures of Effectivess, where the success of the Plan would be a critical consideration. We return to this aspect in the final discussion.

Though assessment may be contrasted with the *design* of such systems, because one is rarely presented with a greenfields approach in contemporary military C2, these are not mutually exclusive practices. Assessment must be part of the design process particularly within continuous improvement and sociotechnical systems design theory which recognises contextual and human-user/participant centric principles [8]. Additionally, though organisational assessment approaches in their early history focused on quantitative methods, particularly the time-motion methods of Taylorism [9] and scheduling/resource utilisation of Gantt [10], the recognition through Max Weber [11] and the Gilbreths [12] of the human dimension of organisational work has driven considerable effort in the means of sociological/ethnographic methods for analysing performance. The centrality of this dimension for C2 assessment has been well recognised, as stated by the Code of Best Practice (COBP) for C2 Assessment [7]: "Human behavioural, physiological, and cognitive factors, along with organisational ... must be considered in C2 analyses". This has become particularly acute with the development of Network Centric concepts for C2 [13]. More than just the connection of hardware systems through wires or wireless technologies, the quality of human collaboration has been elevated as a fundamental property to be measured in C2 assessment [14].

To that end, significant effort has gone into specifying the human variables important to C2, as evident in the NATO reference Model of SAS-050 [15]. With these come a range of methods for collecting data, drawing upon sociological-ethnographic methods but contextualised to organisational work. The fundamental tools of the scientist in this respect, in both *in vitro* and *vivo* settings, are observational notes, interviews and surveys, often with open ended text fields. These are quite demanding of human effort, both in the collection, transcription and subsequent analysis, for example through inductive based thematic methods [16]. There is an additional impost on the subjects of the assessment who must take time from their regular duties to answer questions and provide feedback. The impost on the subject can often be a limiting factor in the data collection for C2 assessments and is a risk for field settings of live C2 systems, as well as the impact of the Hawthorne effect [17], a crude social science analogue of Heisenberg's Uncertainty Principle.

One avenue that has not seen much exploration in the assessment of C2 is the use of digitally gathered C2 data. By digitally gathered C2 data we are referring to data captured by C2 or C2-adjacent ICT applications and systems. We contrast this with instrumentation of a system deliberately in order to gather such data, for example, for quality assurance or research purposes. Here, we show how such data can be acquired through *existing* information systems independently of the scientific endeavor. In this Information Age with cheap processing power and storage options, applications and systems are able to gather large amounts of data at very little cost. The irony is that as the human sciences methods for assessing C2 systems have developed in the last two decades, focusing on individual and collective cognition and teamwork, so too has the footprint of participants of C2 systems in digital systems vastly increased, but remained untapped in analytical studies. Many C2 ICT systems already gather large amounts of data for the purposes of application performance monitoring and auditability. Collecting digital C2 data allows the analyst to not only gather a greater volume of data, but also allows the analyst to do this from a distance without imposing on the subjects of the assessment, at a later date (ambitiously, in near real-time) and at a much higher level of accuracy than could ever be reached by observers. We emphasise that what we mean by digital data is different from using the primary sources of a C2 system, for example the plans, orders and reports of a headquarters, which should also be analysed in C2 assessment using more laborious text analysis methods. Rather, we refer to the meta-data of such artefacts arising from their creation, storage and manipulation in ICT systems. It should be noted that analysing this data in isolation from everything else we have described, even if automatable, will be misleading. Humans are still critical in observing and drawing complex conclusions and themes for C2 assessment from what is a very fuzzy, multi-variate problem space. This paper describes a process that should be seen as a step in a wider endeavour to bring together the data collection methods and platforms of the human sciences together with what we propose here. Indeed, as future C2 technologies (data storage, retrieval and visualisation, and semi-autonomous decision support tools) evolve to more modularised micro-services approaches [18], the integration of such digital assessments of C2 with User Experience (UX) metrics will need to deepen. In this respect, much like streaming services (e.g. Netflix) and on-line shopping (such as Amazon) are able to use Big Data techniques to optimise their service without significant human handling of data collection, so too we may anticipate the optimisation of C2 machine-based services while also transforming the human dimension of C2.

2 Problem setting

To contextualise how we present our approach, we consider the COBP for C2 Assessment [7] which advises that key steps in any study are: the (Sponsor) Problem Statement (linked to feasible Solution Strategies, whereby the means available to the sponsor to solve the problem must be accounted for), Measures of Merit (the issues of interest in the system which for sociotechnical systems will include human, organisational and technological issues in interaction), Scenarios (or contexts of the problems being identified), Methods-Tools-Data, and Assessment of Risks that the issues trigger. While presented here as linear, these aspects (again, emphasised by the COBP) interact *nonlinearly* in the development of any study and therefore cannot be isolated from each other. It is for that reason that digital C2 metrics cannot be developed in isolation from the human factors impacting on C2. Moreover, they offer an opportunity to greatly enhance the measurements of human factors. We also describe these steps up front because of the importance of sponsor engagement and communication with stakeholders in the course of application of these methods.

To zoom in on potential problem statements, we examine the functions of C2. The COBP provides potentially relevant Measures of Merit at the headquarters level: Monitoring and Understanding (information transmission, values, times, effect, comprehension); Planning (information exchange, coordination, impact, flexibility, and process quality); Directing and Disseminating. These are nothing other than particular articulations of the OODA loop, or Endsley's Situation Awareness Model [19] – where Planning is "a formalized procedure to produce an articulated result, in the form of an integrated system of decisions" [20] for *future* actions. In the military context these are based (ideally) on a consideration of the potential future actions by an adversary or threat environment. See also [21] on the Dynamic OODA model, which is specifically articulated for headquarters decision cycles.

To that end, we focus on the example of planning as the theme of a Problem Statement for this study to illustrate how Digital C2 metrics may be employed. There are many variations of the military operations planning process across NATO and partner nations though many of the elements are the same [22] such as Mission Analysis, Course of Action Development and Analysis. As pointed out in Kalloniatis and Macleod [23], planning is a design process [24] seeking to solve an operational problem (which therefore should also design the C2 system for the subordinate entity to the planners). Thus, the steps of Problem Formulation [25] are manifested, with many of the nonlinearities of wicked problems [26] evident in how such processes are actually performed.

3 Methodology

The following is deliberately written in the spirit of a User Guide to facilitate reproducibility of our approach. Although relatively simple, we have developed a set of steps in Figure 1 that we recommend following along with guidance at each step to help analysts get started with using digital C2 data for C2 assessment.

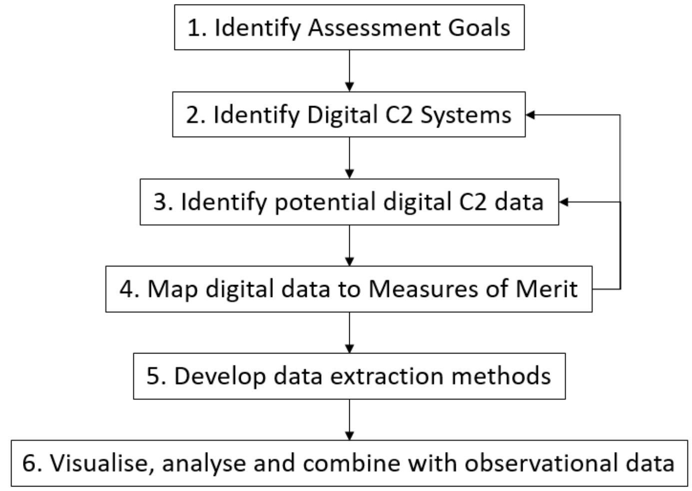

Figure 1 - Digital C2 data methodology

3.1 Identify Assessment Goals

To start off, we need to spend some time identifying the assessment goals that will be met through the use of digital C2 data. When identifying the assessment goals we must first develop a good understanding of the organisational structure being analysed.

- What are the key C2 functions under inspection?
- What are the organisational components within the structure that will be assessed?
- How do the key C2 functions interact?
- What are the constraints and limitations of the C2 systems?

By identifying these goals we can move on to narrowing our focus to the digital C2 systems that are relevant to a particular study.

3.2 Identify Digital C2 Systems

There exists a plethora of digital C2 systems, from the commonly used email system to niche information management tools. While some assist with *Decision making* through automated decision trees, most digital C2 systems fall under the category of *Information Collection and Dissemination* and the enhancement of *Quality of Information*. Within the NATO C2 Reference model (see Figure 2 [15]) this is also referred to as the *Information Domain*. Sifting through and keeping track of these applications involves significant effort in itself.

Therefore, to keep our efforts focussed we establish some guidelines and guidance for which C2 systems to pursue.

- Is the system used by the organisational

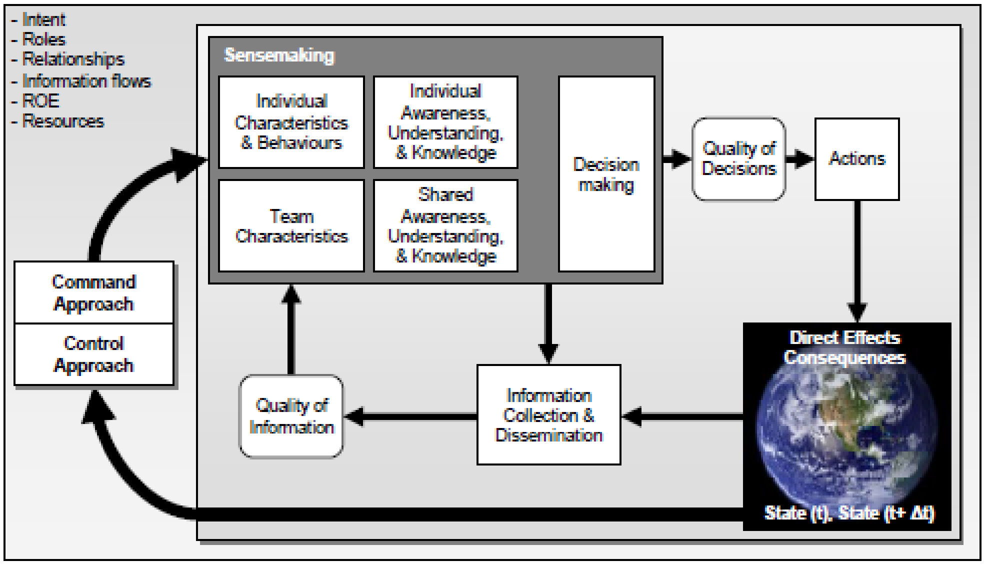

Figure 2 - C2 Reference Model Overview (courtesy SAS-050 NATO) [15]

components and staff identified in the assessment goals?

- Does the system contribute to the C2 functions under inspection?
- How many unique users are there?
- How many components of the C2 organisation use the system, i.e. what is its breadth?
- What level of classification does the system have?

These guidelines help narrow down candidate C2 systems to make the best use of analyst resources. User surveys can help determine the relative priority of C2 systems used by staff, how often systems are used and how many people use the systems. C2 systems that see wide use are more attractive as once tools and scripts have been developed to extract and analyse the data, they can be re-used in future assessments. Finally, an important consideration is to understand the classification of the relevant C2 systems and perhaps more importantly, what options the analyst has for data extraction. Some systems may have a classification which does not allow analysts to independently develop scripts to automate data extraction. Some systems also span across different levels of security classification and may require different extraction methods at different levels.

3.3 Identify Potential Digital C2 Data

This next step focuses on the ease of data extraction and the value of the data once extracted. The ideal case is C2 systems that allow us to programmatically extract data either through the use of a script or application with a high enough degree of resolution to differentiate between users and the actions they are performing.

- Can actions be differentiated by user?
- What user behaviour can be inferred from the available data?
- What is the temporal resolution of the data?
- Can the data extraction be automated with a script?
- Does the system have an Application Programming Interface (API)?

It is preferable to work with a system that allows scriptable extraction of data rather than having to manually work through a user interface. This is especially the case when performing longitudinal studies and examining the change over time as otherwise a great deal of time will be spent retrieving data with no guarantee that extraction will be conducted in the same way. When using an automated process such as a script, we can help remove variability introduced by differing collection methods potentially improving data validity.

A common issue throughout this process is that the selection and use of digital data requires an iterative approach. Only by extracting, visualising and analysing the data can we begin to draw insights from the data and what it can tell us about how the C2 is performing. This step in the process should be accompanied by exploration of the data with prototype scripts and methods for extraction coupled with some quick visualisations to see if there is merit in further analysis.

3.4 Map Digital Data to Measures of Merit

When considering how to measure the performance of command and control, we must identify the concepts we are going to measure. Naturally, we start with the NATO C2 Reference Model [15] which provides a starting set of

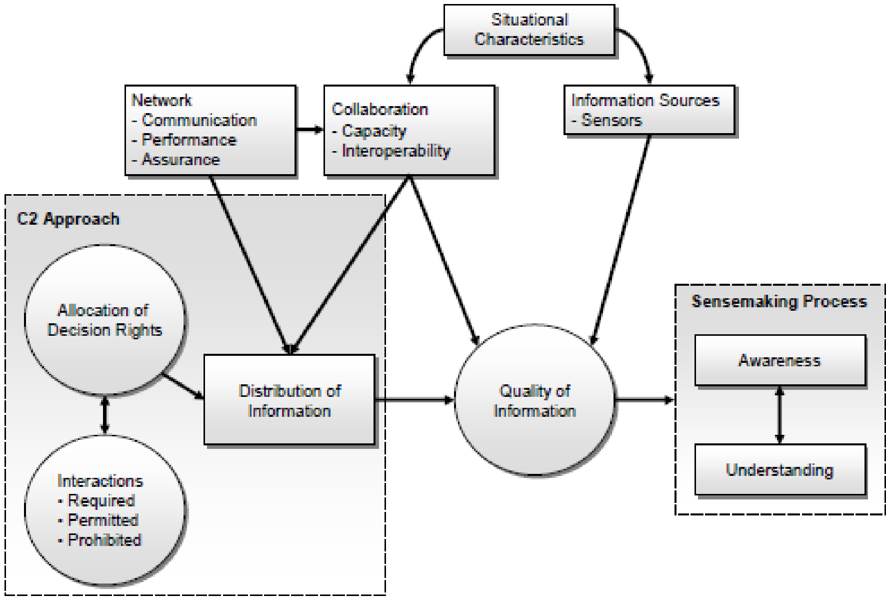

Figure 3 - Information Domain Variables (courtesy SAS-050 NATO) [15]

variables that contribute C2. This model of over 300 variables and over 3000 relationships, while long, is not exhaustive and nor are all of these variables necessarily relevant to what can be captured digitally from C2 systems.

As noted in the NATO C2 reference model, the key influences on the distribution, collection and quality of information are the characteristics of the network, the ability to collaboratively access, update and synthesise information as well as the characteristics of the information sources i.e. sensors. While most of the identified variables in the reference model could be used to measure digital C2 systems, we have identified a smaller set that is more relevant to the digital systems that we are interested in observing. That is, information management and collaboration systems. These relevant variables identified from the NATO model are as follows:

Network Characteristics:

- Network reach: The number and variety of staff and organisations.

Information Assurance:

- Integrity: The division of information across and within systems.
- Non-repudiation: Knowing with certainty who provided information.
- Network availability: The amount of system downtime experienced.

Collaboration:

- Collaboration completeness: The spread of relevant contributors.
- Frequency of interactions: The frequency at which staff interact with the system
- Interaction quality: The usefulness of the interactions.

Interoperability:

- Data interoperability: The extent to which data from one system be used directly in another without transformation.

Information Quality:

- Information currency: The time lag of shared information.
- Information timeliness: The relationship between information availability and when it is needed.
- Information shareability: The extent to which information can be accessed and understood by all nodes of a network.

The variables noted above can be grouped into some broader categories. Firstly there are *User Characteristics*, arising from how users interact with the system, i.e. the number of and diversity of users along with the actions they are performing. Note that in this category we do not refer to users as named individuals, who will always be obfuscated or genericised. Secondly there are the *System Characteristics*, namely how well the system performs whilst under load, and the degree of interoperability with other systems.

The System Characteristics are relatively static; data interoperability between systems does not change overnight and, while the computing resources allocated to applications can be varied, this primarily affects responsiveness and error rates. These System Characteristics are not inherently effected by different C2 scenarios. The load imposed by users may change but the system performance will be roughly known. System Characteristics are useful to observe when we are examining if a system needs to be upgraded or replaced. For example, a user may complain of poor performance of a C2 system and by analysing the System Characteristics we can determine if the user's complaint has merit.

The User Characteristics on the other hand are much more dynamic. By tracking which anonymised users are using a system and what actions they are taking, we can begin to build a digital thread or narrative relevant to the C2 behaviours of the unit at an appropriate level of fidelity. This breadcrumb trail of user actions can tell us how many different users are collaborating on a process or artefact, how long it is taking to complete the process or artefact, and, after the process or artefact is finished, its usefulness can be estimated based on the level of interaction from other users. User characteristics therefore give insight into the dynamism of C2. Nevertheless the System Characteristics give insight into the impediments to this dynamic behaviour by the technology infrastructure.

We should note that the list of variables identified is by no means complete, rather it is a starting point to which much of the gathered metadata can be easily linked. There may very well be other methods of analysing the data that may reveal new variables within the COBP that we can trace to.

3.5 Develop Data Extraction Methods

There are many different ways we can extract digital C2 data from C2 systems. Some systems allow navigation and inspection of data within the application itself. This form is the least useful as data must be transcribed manually and is labour intensive to locate. The data is also static, once it is extracted the analyst has to go back and repeat the process to get any updates (if they exist).

Other systems have more powerful methods of accessing and retrieving data. They may offer complex search queries and an option to export results to some file format. While a step up from the previous method, this still has the issue of being quite manual in nature and again requires that the analyst revisit and spend time re-exporting for new data. The best methods for extracting data comes from applications that provide an API that can be programmatically accessed by a script which returns the C2 data in files that can then be processed. Alternatively, if the C2 system is a web application, it is also possible to set up a web scraping script that can extract data directly from web pages. A similar alternative in some C2 systems is the ability to set up alerts that can send data periodically via email to an analyst whenever updates occurred. This method is useful in that there is no additional effort required to extract the data, however it does require these data taps be set up in advance.

3.6 Visualise, Analyse and Combine with Observational Data

The final step in the process is the visualisation and analysis of the data. At this point it is vital to bring in any observational data collected to build an overarching narrative of events. C2 digital data by itself cannot tell a complete story of what happened during a period of assessment. There are many interactions and activities that are not captured by digital systems and without these nuanced observations, the digital data analysis may lead to incorrect conclusions. A useful visualisation between different C2 systems is a scatter plot of actions, which may be grouped in a variety of different ways. It may be useful to group actions by user, by branch, by directorate or by application. The next step would be to overlay a set of observed events from the observational data over the digital data. This could include key events that were observed during an exercise or the execution of pre-defined events such as those from a Master Scenario Event List (MSEL). These overlaid events can then be compared with actions undertaken on digital C2 systems to help quantify the lag between events and actions.

3.7 Methodology Conclusion

By following the aforementioned steps, we may draw an initial set of conclusions based on the NATO measures and integrate the results with traditional sociological and organisational analysis. The true power and value from this use of digital data will be in longitudinal studies where we can repeat assessments and view the differences in quantitative results over time. Measures such as timeliness and total interactions can be tracked and compared year to year which can help track the improvement (or otherwise) of C2 processes and systems.

4 Application to the Operational Planning Process

The ADF's Joint Operations Command (JOC) has been undergoing a steady transformation over recent years. Plan MURA is the overarching headquarters modernisation plan covering four distinct Lines of Effort (LOE): C2 Organisation, Workforce, Operational Information, Networks and Applications (OINA), and

Infrastructure. One of these transformations under the C2 LOE has been a reshaping of the planning (J5) and operations (J3) branches to allow for more seamless planning through to execution with the introduction of Integrated Operations Teams (IOT) as proposed by [27].

IOTs are geographically or thematically focussed teams that take on the functions of the traditional J35, J53, J8 and other areas of expertise to conduct operations. The driving force behind this new construct is the removal of the barrier between planning and execution and a focus on team-shared mental models through the process, rather than the product. This allows staff to experience the entire process and incorporate lessons learned in the next cycle of planning and execution.

As this is a novel C2 organisational structure and a departure from the traditional Common Joint Staff System (CJSS), it is important to assess this change and see what is working well and what is not. An assessment of the new IOT structures has been centred on the conduct of a Command Post Exercise (CPX) in which the staff must employ the operational planning process of the ADF, the Joint Military Appreciation Process (JMAP), to respond to a scenario. The observation and analysis of planning activities through the CPX provides a relatively controlled environment in which to assess C2 and the changes introduced by the new IOT construct.

Following the process described in our methodology, we identified the key C2 function under inspection as the Operational Planning Process, and the key components under inspection were the newly formed IOT structures.

Having identified the functions and staff, we went on to identify and shortlist the C2 applications that were involved in the conduct of operational planning. The key systems that were identified in this assessment were a document management system and a web-based collaboration tool. The document management system is used extensively across all branches within the headquarters and is a key system for storing plans and planning artefacts. The web-based collaborative tool is also used across branches within the headquarters for managing exercises and plans.

Having identified the applications themselves, we looked at the data available from these C2 systems. The document management system tracks actions such as when a document is opened, when it is locked for editing and released with changes along with the user who performed the action. This document management system also provided an API which could be used to automatically extract these actions which made it very attractive in terms of scalability and ease of use. The user behaviour that can be inferred from this data was who within the IOTs was contributing to the plans and who was then going on to access these plans, giving an idea of the interaction and 'usefulness' of the plans. After anonymising individuals here, it was possible to infer the time taken between a specific event and when work on a formal artefact began and finished. The web-based collaboration tool also offered similar data with timestamps, action types and associated users.

The next step in the process was to map the available data to Measures of Merit. The inferred user behaviour from the document management system was used to measure:

- *Network Reach*: The variety and number of unique users (given a numerical distinguishing designation) using the system.
- *Collaboration completeness*: The spread of staff from different branches contributing to the development of a plan.
- *Frequency of interactions*: The rate at which staff are accessing and interacting with planning artefacts.
- *Information Currency/Timeliness*: The time it takes for a plan to be developed and the currency of information in a plan.
- *Information Shareability*: The extent to which information is shared across nodes of the network.

With the Measures of Merit in mind we worked on the data extraction methods, which primarily utilised scripts that could access the document management system's API to retrieve the relevant user actions.

Although we are unable to show the actual results, we combined the extracted data with a number of observations from the CPX period and used some of the collected data to corroborate statements made in follow on interviews. This provided a solid baseline of quantitative values for *Network Reach*, *Collaboration completeness*, *Frequency of interaction* and *Information Currency and Timeliness* to compare in future CPX events.

To provide an artificial, though insightful example, a small research team of 7 (non-military) members was analysed using data gathered from a 3 month period from the document management system. The data itself is not representative of a real headquarters but serves to illustrate how this data can be used to infer user behaviour and, by extension, provide measures of merit.

In Figure 4, we show a directed network graph showing the flow of information between the anonymised users according to the event log in the document management system. An information flow was defined as a user modifying a document and another user then accessing the same document within a week. A weighting was also applied to the edge based on the time delay between the modification and the access with a higher weighting applied to a shorter time delta between events.

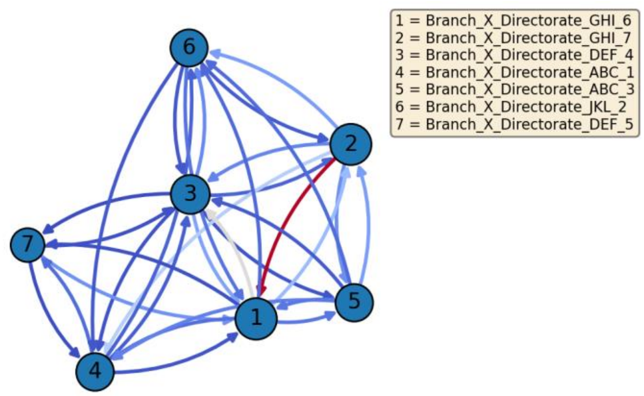

Figure 4 - User to User Interaction

The graph numbers the nodes in descending order by the combined edge weight and the links are coloured by weight with dark blue being the lowest weight edge through to dark red being the highest weight. From this graph we may infer the level of collaboration completeness within the team as being relatively high, but with fastest interaction occurring between users 1 and 2.

The same research team can be roughly grouped into 4 sub-teams and we can view the interactions between these sub-teams.

This allows us to see how tightly linked the teams are and the extent to which they are sharing information (Figure 5). If there is a significant change in process or team structure it would be a simple matter of comparing the network graphs over two separate time periods to see where the new information flows exist. These network graphs are based on quantitative digital data, as opposed to human observations, that can be compared to see if information flow has increased or decreased over time.

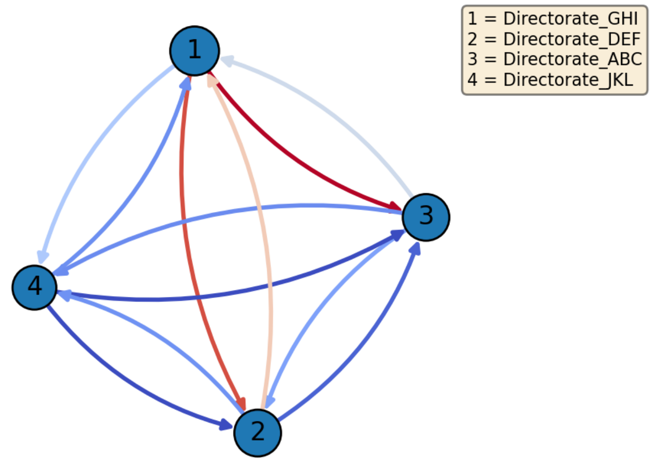

Figure 5 - Sub-team to Sub-team Interaction

In a similar vein, we provide an indicative example of how we were able to track the development of planning artefacts over the course of an Operational Planning CPX event. The points shown in Figure 6, denote modifications to planning artefacts and how they are sequenced in relation to formal steps of the Operational Planning process. Again, individual interactions with a document by users are de-identified. Here we have abstracted the time steps on the horizontal axis, and indicated the planning process steps on the vertical with earlier steps at the top and later at the bottom.

While generally showing a progression in time from left to right and stepping through the process from top to bottom, what is most evident here is the nonlinearity of the realised process: documents related to an earlier step, for example Mission Analysis, are being revisited even as Courses of Action (COA) are being developed later in the process. This is consistent with previous research based on qualitative observations and analysis of headquarters planning [23] of how the dynamics of wicked problems [26] manifest in a 'zig-zag' path through the process, first recognised for wicked problems by Conklin [25]. Other observational data may then be overlaid on such an analysis of the digital footprint to understand the context and the triggers in the environment driving such nonlinearity.

5 Future Work and Challenges

One of the main problems in expanding this framework is tracking events and activities between C2 systems. For example, data collected from one C2 system may be in a different format to that gathered from another system. It is very difficult to follow the 'digital thread' that spans across multiple standalone systems. For example a staff member may receive an email with new information

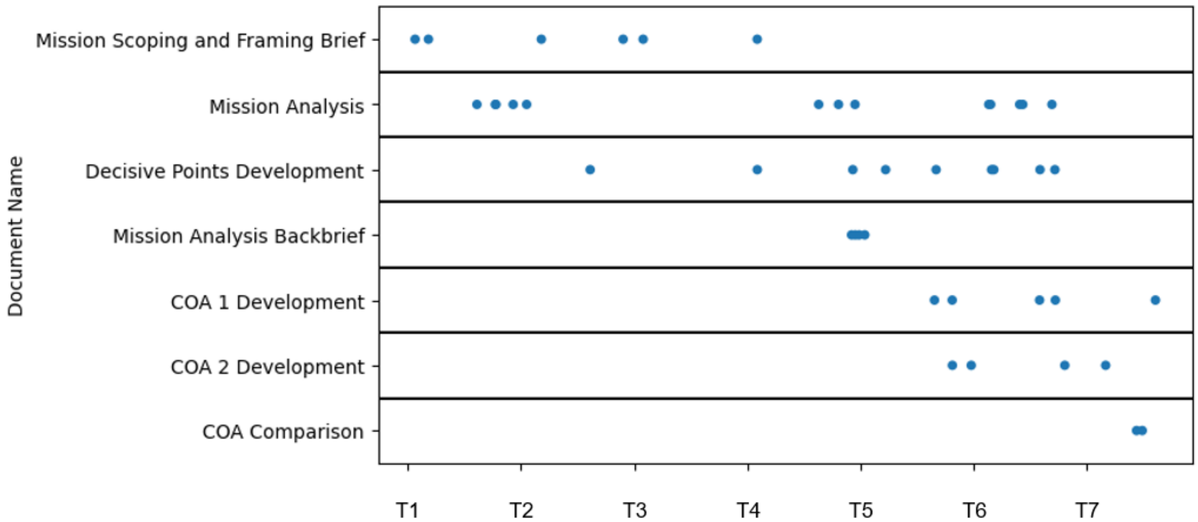

Figure 6 - Indicative Planning Artefact Development. Time steps Ti represent discrete time-intervals and the vertical axis show the formal steps of the planning process.

whereby they may need to generate an additional slide in a PowerPoint plan with the use of a new geographical information system map or layer and then update a plan document. This thread spans only three digital C2 systems but is very difficult to trace as the formats between systems for capturing audit events vary, as do things as simple as user IDs. A username on one system is not guaranteed to be the same on another. The development of a standardised data format along with a shift towards Single-Sign-On (SSO) applications with common usernames could be done so that we may more easily combine data from several C2 systems at once.

Additional challenges lie in combining datasets from C2 systems across differing classification levels. Humans are typically more capable of switching between classifications rapidly and using information garnered from a lower level classification system in a higher level system. Tracing the digital thread from lower level to higher level classification is very difficult and yet forms a key component of day to day life in a modern headquarters.

This work represents the initial steps in standardising the collection of digital C2 metrics and integrating them with traditional data collection methods. Future work can be decomposed into three main categories, the first is to further explore the art of the possible by analysing the breadth of the digital data available to find further correlations and interactions of interest that can either directly identify, contribute to, or supplement, C2 metrics. The second category of future work is to standardise the collection and integration of digital C2 metrics with the context, circumstances and nuances that are obtained through human analyst observations from traditional assessment teams. The ultimate goal lies in the potential to develop real-time, or near real-time, C2 metric and assessment capability. Finally, and more profoundly, we seek to be able to correlate the measures thus acquired against data (digital or otherwise) that characterises success in the operational environment so as to achieve Measures of Effectivess. We have undertaken this with digital data for some real world operations where speed of execution was critical but are unable to report on this in this forum. Linking our methods to simulation models is another way to accomplish this manageably. For example, data collected in this way may be used to inform mathematical models such as given in Ahern et al [28]. This would be one way to close the loop on the C2 measurement problem.

6 Conclusion

In this paper we have discussed the merits of using digital data from C2 systems to assist in the evaluation of C2. We have also presented a generalised method for using digital data in C2 analysis. This included identifying the relevant C2 systems, identifying the available and useful data from such systems, and mapping that data to NATO C2 measures of merit and variables. The paper provides advice on how to setup data extraction tools and finally discusses how to combine and visualise the data overlaid with information gathered by humans directly through observations.

Key attributes of digital C2 systems were found to fall within two major categories: user characteristics and system characteristics. The user characteristics can be used to assess the behaviour of users while using C2 systems whereas the system characteristics can be used to assess the performance of C2 systems especially while under load.

The methodology was successfully applied to a real world example of Headquarters Joint Operations Command conducting an Operational Planning CPX using its operational planning process which resulted in measurable insights when combined with traditional data collection methods. Specifically, we were able to see how teams were interacting with each other through the medium of the documents and artefacts that they work on. Also, we were able to map out the nonlinearity of planning, with insights consistent with qualitative observations in past research. While only a first step, this capability offers an exciting opportunity to be truly holistic in data collection and analysis of C2 systems through the entirety of their sociotechnical dimensions.

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