

13TH ICCRTS
“C2 for Complex Endeavors”
**Exploring alternative Edge versus Hierarchy C2 Organizations using
the ELICIT platform with Configurable Chat System**
Track 7 – Network-Centric Experimentation and Analysis
Track 5 – Organizational Issues

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ABSTRACT

The Edge Organisation is a subject that warrants much research and experimentation within the C2 research community. By combining the ELICIT Multiplayer Intelligence Game with the use of CHAT, we designed an experiment to test the effect of different rules of information-sharing, communication, and decision-making on the performance and behaviour of three different permutations of Edge versus Hierarchical Organizations. Our main findings suggest that when an intelligence organization is tasked to analyze incoming data and decide on an interpretation of these data, the edge organization outperformed both the traditional hierarchy and the edge-hierarchy hybrid over decision speed, decision accuracy and level of shared correct awareness of the threat situation. The hybrid organization and the traditional hierarchy performed equally well on decision accuracy and shared awareness, but the former made decisions faster than the latter. One possible explanation for our results is that in the hierarchical structure, the processing of information takes place in two different levels subsequent to each other in time, but in the Edge there is only one processing level. Through this experiment we also demonstrated how intra-organizational behavior and command chain leadership issues can be addressed through introduction of different CHAT configurations to complement the ELICIT platform.

INTRODUCTION

Network-Centric Operations (NCO; Alberts & Hayes, 2003) proposes a shift from the traditional military hierarchical command philosophy to a structure where forces are more nimble and operate on networks to increase their shared awareness as well as to self-synchronise with one another, herein called as the *edge organization*. Alberts and Hayes (1999) point out that the translation of the NCO concept into a real operational capability requires more than the implementation of information technology and networks. They defined a Mission Capability Package (MCP) comprising concepts of operation, C2 approaches, organisational forms, doctrine, force structure, support services, and the like that is required to leverage information superiority in the realisation of NCW. Alberts and Hayes in their book ‘Power to the Edge’ maintained that empowerment involves “the ability to provide and access available information and expertise and the elimination of procedural constraints previously needed to deconflict elements of the force in the absence of quality information” (Alberts & Hayes, 2003, p. 5). This paper aims to present the research and experiments carried out jointly by the Singapore Armed Forces Centre for Military Experimentation (SCME), the DSO National Laboratories of Singapore and the National Defence College of Sweden, towards Edge organization concepts.

The effectiveness of the military outcome is extremely dependent on, and highly intertwined with, how it applies Command and Control (C2) to the force, in order to achieve its predefined mission objectives through a series of planned actions. There is a chain of effectiveness in what the military does. On the one hand, there is effectiveness of the supporting tasks to the mission objectives such as fires, intelligence gathering and logistics, and on the other, there is the accomplishment of the mission objectives at the tactical, operational theatre and strategic levels. To achieve the above, the military designed a doctrine of fighting and spends a large part of the time training and educating the forces on standard operational procedures, processes, orders, cultures, teamwork and, of course, the art of fighting in combat (e.g. US Army, 2003; 2005).

C2 in itself is a complex and dynamic task. Once the mission objectives have been defined, it may only be a matter of hours that the mission objectives and the constraints by which the force is to accomplish the mission would change, as experienced in past

conflicts and war (e.g. Simpkin, 1985). The planned action becomes outdated and there is a need to dynamically review the mission objectives and constraints continually in order to develop adjustments to the plan of action. The possibility that the adjusted planned action will need to be changed again is high, since each time the “thinking” enemy is also adapting and changing her strategy, objectives and planned actions (e.g. US Army, 2003).

Different methods of C2 may be employed to effect the dynamically changing plans. These include centralized command and control; centralized command and decentralized control, decentralized command and centralized control and finally, decentralized command and control. Centralized command and control has the advantage of prioritising the allocation of resources to the theatre, but this is seldom practiced by the Army and the Navy of most nations due to the structured echelons of command found in large militaries. At the other extreme of the C2 spectrum is the decentralized command and control concept that allows the force at each echelon to have total command and control, herein also called as the *Edge Organization* (Alberts & Hayes, 2003).

For all of the above command and control structures, there are two primary practices to facilitate commanding independent forces with authority, namely mission command and detailed command by planning (Wilbeck, 2003). Mission Command seeks to direct the sub-ordinate commander with clear intent such that the lower echelon’s planned actions would flow in accordance to the higher echelon’s needs and intent (c.f. Builder, Bankes and Nordin, 2000), while detailed command seeks to exact the detailed plans that each lower echelon would have to abide by, thus only allowing the commander freedom in troop disposition, morale, weapon composition, and perhaps logistics. (Wilbeck, 2003). The practice differs from military to military. At this juncture, the authors will not cover the more complex problem of having two or more militaries with different C2 methods or cultures to work together in a coalition setting.

Nevertheless, within a particular military organization, there could be a danger that a particular method of C2 may be the proverbial Achilles heel to the entire operations, whether in loss of time, resources or the loss of control to gain advantage over the adversary. As an example, a military could practise a centralised command and control of air resources, which for all intents and purposes would be the most flexible way of

directing aircraft resources if they are scarce. However, if a request for air strike directed upwards from the Battalion requires concurrence at each chain or level of command, it would take a long lead time for the aircraft to finally strike on the enemy target, during which the enemy would have had sufficient time to prepare himself or to take up advantageous positions over our own forces.

There is therefore a need to be adaptive in the nature we command and control our forces. The idea is to adopt a practice for militaries to flexibly move across any one of the described C2 structures in order to adapt to the various scenarios such as manoeuvre, precision strikes, logistics, etc. over several contexts such as homeland security, operations other than war, and war itself.

As a way forward to adopt this approach, the SAF Centre for Military Experimentation (SCME) began an experiment campaign in 2006 to determine if troops could achieve what is called as the ‘Distributed and Integrated Command Environment’ or DICE for short. Cheah and Fong (2006) explained that DICE proposes a command environment that would allow the Commanders or the organization to adopt not only the traditional military hierarchical command philosophy, but also a force structure where the edge elements, that is, the disparate fighting units, are empowered with the information they need as well as the authority to collaborate and self-synchronize in the effective execution of distributed and dynamic operations as they adapt to the changing battlespace situation. Translating, DICE essentially is a concept for forces to work distributed across the battle space, in turn leading to a less hierarchical force structure and allowing a subordinate commander, for instance, to address his issues not only to his immediate superior but also to a circle of experts and higher command through a collaborative operational picture. The US Marine Corps concept of distributed operations is a similar effort to DICE (Hanlon 2004, Schmidle & Hoffman, 2004), but without using the word “self-synchronization” at this juncture.

SCME conducted a limited objective experiment (LOE) in an air-land scenario and consisting of forces from both the Air Force and the Army, showed successful results in the adoption of the edge structure where authority for helicopter troop carrying operations (the MCP) lie with all the heli-pilots and the respective ground commanders going on-

board the craft (Cheah & Fong, 2006). However, such experiments conducted by SCME, while realistic in operational approaches is also quite costly. To fulfil and experiment all the various MCP that can adopt the DICE concept, without an initial laboratory test for each one, could turn out to be a very expensive affair, and may lead to the experiment controllers being more risk adverse in their experiment approach.

The ELICIT Multiplayer Intelligence Game

Parallel efforts in experimenting with edge organization, and much less expensive in terms of developmental cost and troops, have taken place in 2006 by the CCRP community such as Evidence Based Research, the Naval Postgraduate School (Lewelling and Nissen, 2007) and Parity Communications (2006), a company who have developed a platform called the Experiment Laboratory for Investigating Collaboration, Information-sharing and Trust or ELICIT for short. ELICIT is an initiative sponsored by the CCRP for C2 research community to research and experiment differences between hierarchical and edge organization concepts. The present software of ELICIT (Ruddy, 2007) requires a team of 17 subjects performing the roles of intelligence analysts to collaborate, in a network centric, information processing environment, with the goal to identify a fictitious and stylized terrorist plot. In the Elicit Game, the experimental task is for every subject to identify the “who”, “what”, “where” and “when” of an adversary attack based on simple information facts (called “factoids”) that become known to a team. The original ELICIT Game is designed to compare the edge versus the hierarchy, therefore the independent variable in ELICIT is whether a team is organized using traditional Hierarchical Organisation or using Edge organization principles. Each game requires 17 players and the players are randomly assigned with pseudo-names, and organized in either a Hierarchical or Edge organization, to perform the required tasks. Putting the game in real-world context, the organization can be seen as an intelligence organization that has to analyze incoming data and inform its client (or government) about the assessment.

Enhancing Relevance to Real-World C2 Organizations

However, the current ELICIT software does have a discernible limitation. A key consideration in achieving shared awareness, and also being able to trust and collaborate

should be the ability to provide inputs by one subject to another and get a response from that subject in return. This is not available in ELICIT and thus experiments conducted by several communities are arguably less valid to test whether edge organizations are better performers than hierarchical ones. Another limitation is that ELICIT currently only provide two forms of experiment play and that is, hierarchical and edge. There is no in-between or hybrid at the time of writing this document, which could be of the more acceptable nature for organizations willing to try edge structures but cannot do away with their current hierarchical structure culture.

In our contribution to CCRP and also the authors desire to ensure operational teams have a definitive knowledge of edge structure performance prior to extensive field experiments, the authors put forth an in-house chat module (henceforth known as CHAT) to supplement the limitations that are apparent in ELICIT. As modern information technology makes it way into current C2 organizations, web-base communication tools such as online-chat becomes a possible way for different roles and groups in an organization to communicate and interact. With CHAT, subjects can now get immediate response on a topic, fact or an analysis, and at the same time, use group-based CHAT as a means for achieving shared awareness and facilitating reporting structures. With CHAT, communities can now experiment broadly many concepts with respect to C2 structures and approaches, allowing researchers and even subjects to gain greater insights in collaboration and information-sharing.

OBJECTIVES OF EXPERIMENT

As presented in the introduction, there is reason to assume that some of the problems facing commanders carrying out new kinds of operations (e.g. stability operations) could be attributed to the maintenance of a less than optimal organizational structure of the force (i.e. a strict hierarchy; Dynes, 1994). At least in theory, and based on computational and laboratory tests (e.g. Lewelling and Nissen, 2007; Parity Communications, 2006), the edge-organization seems to be better suited to deal with these problems, and that is why efforts to further investigate the potential advantages and disadvantages of the edge versus the hierarchy is important.

Exploring Features of Edge, Traditional Hierarchy and Hybrid C2 Concepts

The purpose of this experiment was to explore and compare the effectiveness of the edge organization versus a traditional C2 hierarchy as well as a hybrid of the two C2 organization, where the strict rules of the hierarchy are relaxed in some important aspects (i.e. concerning access to information, communication across organizational boundaries and decision making), but to all intent and purpose, the organization is still a hierarchy. There are several reasons for putting a hybrid C2 organization to test. For example, in some missions such as peace-enforcement, humanitarian aids, emergency response and others, it is not viable to get a sole commander on the ground to make the decisions as there are many stake holders beyond the military influence. In other situations, there are often several coalition partners or several cooperating organizations that have to make decisions as a committee (consensus) or at least make decisions by majority or plurality. Also, access to information is often enough not so stove-piped and restricted as it was used to be, because access to information can now be through common web sites. A third reason for testing a hybrid C2 structure is that email and chat has become quite prominent in recent years and have made communication across organizational boundaries easier than before.

Incorporating CHAT as a medium for interaction

Similar to previous experiments performed under laboratory conditions, the ELICIT Multiplayer Intelligence Game formed the basic framework for our experiment. However, the present ELICIT software includes no means of communication among the players, of emergent ideas or conclusions related to the task they are solving. In other words, they are not able to interactively share their mental models in real-time. In the version of ELICIT used in previous experiments the players can only communicate ready made pieces of information to each other, or post/pull such pieces of information on a web page. Without altering the features of the current ELICIT software, we operated CHAT (in different configurations) as a communication channel among the members in the organization to get a richer and more realistic game environment.

Different Methods of Making Decisions

Another aspect that we wanted to include in our investigation was organizational decision making. A traditional hierarchy normally makes decisions at the top, by the commander. In the edge organization it is not so clear how the organization as such makes decisions, but the general idea seems to be that in the edge, everyone has the right to decide how to act for them selves (Alberts & Hayes, 2003). There are however other ways for an organization to make a decision. For example, making decision in a committee or coalition, where the decision makers all represent different areas of responsibility or expertise and they are forced to make a decision in consensus, or at least, by majority. Another example is if an edge organization has to come up with a (common) decision. Then such a decision could be made by majority or plurality or some other decision rule. We set out to combine both different configurations of CHAT and different decision rules with the basic ELICIT game in order to explore and compare three different kinds of organizations.

Traditional Hierarchy

The first structure we decided to explore can be seen as a **Traditional Hierarchy (TH)**. It has four functional or specialist groups of *analysts*, and each group is directed mainly towards one of the four questions, posting information they receive individually on a team website (the where-team has a where-website etc). They are the only analysts who have access to that website. Information they receive that does not concern their specific question can be sent to specialists in other teams (but not posted on their team websites). Heading each of the four teams is a *team leader*, who has the same access to information as the members of his team. On top of the four team leaders is the cross team coordinator who is the head of the organization, the decision maker (in ELICIT he, they were all male, is called the *cross-team coordinator*). He has access to all functional websites and he, as well as the team leaders, also participates in the analyst work, receiving information on the terrorist plot through the system. In this organization the cross team coordinator has a key role concerning the completeness of situational awareness within the whole organization, because he is the only one who has access to all four web sites.

Regarding communication through CHAT, in TH all analysts can communicate with each other, also across teams, and with their own team leader, but they cannot communicate directly with the commander two levels up, the cross-team coordinator. Such communication must go through their team leader. We regard this restriction as a common trait and process of a traditional hierarchy. All team leaders can communicate with each other and with the cross team coordinator.

The organizational decision making in TH is done by the cross-team coordinator, and he submits his final assessment of the threat (all four parts/questions) when he feels certain about it. It is expected that the team leaders for the four different functional teams are supposed to provide him with an answer on their specific question.

Edge – Hierarchical Hybrid

The second structure we explored was a **Hybrid (HY)** between a traditional hierarchy and an edge organization. It is still specialized with four functional groups of analysts, but here the analysts, and the team leaders, have access to all four functional websites. As in the TH all members of the organization will receive individual information vital to answer some part of the four questions. Concerning communication in CHAT, the CHAT set-up in HY allows everyone to interact with everyone else, so the restriction in the TH for analysts to communicate directly only one level up is removed in the HY.

Concerning organizational decision making in HY this is made by majority in the group of team leaders and the cross team coordinator. When three out of five in this group agree on all four questions, they can submit their common answer, as the assessment made by their organization to their client. This way of making decisions actually makes this organization a two-level hierarchy and not a three-level, as the TH. The cross team-coordinator is not superior to the team-leaders but on the same level as them. His “vote” has not more merit than the votes of the other four members of the command group.

Edge

The third structure we explored and made comparison with the earlier two structures mentioned was the **Edge (E)**. In this structure there are no functional (specialist) groups and no team leaders. All members are analysts with the same mission and they are free to choose (self-synchronize) in what area they want to focus. As in the other two

organization types all members of the organization will receive individual information vital to answer some part of the four questions. Concerning communication, the CHAT set-up allows everyone to interact with everyone else.

Organizational decision making is done by majority among the analysts. When nine out of seventeen analysts agree on all four questions, they report or submit their assessment to their client. This way of making decisions in the edge organization can be seen as a violation on the basic idea of the edge or as taking the edge of the edge. The basic idea in the theory about the edge organization as it is presented in Alberts & Hayes (2003) is that in the edge, each agent is so well informed on the overall intent and has the same high level of shared awareness as the other agents in order for them to decide individually. Imposing a majority rule for organizational decision making upon the edge organization would be to “miss the point”. Although we agree on the basic assumption of the edge, we still wanted to test if the edge could be effective also in a situation where it has to agree on a common decision. In today’s world of coalitions and consensus building before action can be taken we thought that imposing a majority decision rule upon an edge organization was easily defensible and also interesting enough to investigate further.

The 3 experimented structures are described in more detail in **Appendix 1**.

EXPECTATIONS

Regarding what expectations to have concerning the effectiveness of the different organizational structures, earlier research based on the ELICIT game gives some direction. However, earlier research using the ELICIT did not include the ability to communicate two-ways among players and not the decision-making rules. The adding of these features and the small number of participating teams, resulting in a small basis for proper statistical analysis of results, restrained us from formulating and testing strict hypotheses. Instead we formulated a few expectations to evaluate.

Decision Making Time

Concerning *the length of time* it should take for the different types of organizations to come up with their decision (assessment), earlier research indicated shorter time for the

edge (Lewelling & Nissen, 2007). However, as their experiment did not include the majority rule for decision making, we postulated that the implementation of this decision rule into the edge organization to be rather time consuming for the members of the edge to derive a majority agreed decision as compared to the situation where a single decision maker makes the decision, as in TH, or when a smaller group have to agree on the decision, as in HY. Thus our expectation was that the edge should need longer time to submit its organizational decision on a full assessment of the terrorist threat, followed by the HY and then the TH as the fastest organization to make decisions.

Accuracy of Decisions Made

Concerning the level of *accuracy of the decision* (threat assessment) delivered by the different organizational types, earlier research gives no guidelines because no decision rules like the ones we used were imposed. We postulated that the decisions made by majority, as in the edge but also, in smaller scale, in the HY, should at least in theory be more elaborately discussed and assessed. The risk that a false conclusion should go undetected should be less, because more individuals with shared responsibility for the correctness of the complete assessment should have processed the information underlying the assessment. Thus we expected the Edge (which should involve the most number of players debating and agreeing on the complete answer) to deliver the highest level of accuracy in the decision, followed by the HY and then TH.

Level of Shared Awareness

Regarding the level of *shared awareness* of the threat we defined it as the level of common agreement among the players in an organization, on the correct answer on all four questions. The interesting point to note here is whether a certain organization structure would result in a higher level of *correct* shared awareness or less. Shared incorrect awareness, if formed, is not a good thing for any organization as it means that the organization commonly believed in a wrong perspective of the truth. The reason for including such a measurement is that shared awareness is a part of the NCO value chain, were it is described as a precondition for successful self-synchronization (Alberts & Hayes, 2003). Our definition of shared awareness means that this measurement in part

captures the same phenomenon as the measurement of decision accuracy, but here we are interested in the overall proportion of players in each organizational structure that finally agrees on the correct assessment. On this, earlier results gave mixed signals because in the study by Lewelling and Nissen (2007) there was no difference in level of shared awareness between the edge and the hierarchy, but in the study by Parity Communications (2006), the edge performed better than the hierarchy. We postulate that the edge, at least in theory, should allow more individuals to engage in constructive discussions, through CHAT, regarding the full assessment of the game outcome as opposed to the situations in TH and HY where analysts assigned to solve parts of the task would only discuss relevant components of the assessment. Therefore we expect the level of shared awareness to be highest in the E, followed by the HY and then the TH.

EXPERIMENTATION METHODOLOGY

Design of Experiment

Although we did not design this study to test hypotheses we still employed an experimental design. Independent variable was the *type of organization* in three different levels: (I) the Traditional Hierarchy (TH), (II) the Hybrid between a traditional hierarchy and the edge (HY) and (III) the Edge (E). The difference between the three types is described in the previous section and in **Appendix 1**.

Participants

The experiment involved the entire graduating cohort of senior male and female military officers (MAJOR, and some LIEUTENANT COLONEL in Rank) from the Singapore Command and Staff College (SCSC). The participants were organized into 7 teams, with a random mix of training background (army, navy and airforce), and they were all reasonably equal with respect to their military experience and age. Since the team compositions were comparatively on par in terms of operational capability and seniority, we did not measure any background variables, and also partly because earlier testing did not show any substantial relationship between experience from analyst work and the performance on the ELICIT game (Lewelling & Nissen, 2007).

Procedure

Each participant went through a training run before their actual run. One scenario was used for the conduct of the training runs, and another scenario was used for the conduct of the actual runs. Before the commencement of each run, the teams were briefed based a standard set of instructions developed. The detail procedure is described in **Appendix I**. The breakdown of the C2 concepts experimented by all 7 teams were listed in Table 1.

Table 1 - Number of teams in each experimental condition

C2 Concept	Number of Teams
Level I – Traditional Hierarchy (TH)	2
Level II – Hybrid (HY)	2
Level III – Edge (E)	3

Dependent Variables

Dependent variables were (a) *decision speed*, inferred from the time taken for the organizational decision maker to deliver the team’s decision/assessment on all four questions; (b) *organizational decision accuracy*, inferred from the proportion of correct answers on all four questions (the “what”, “where”, “who” and “when” questions) delivered by the head of the organization, for that specific organizational structure; (c) the level of *correct shared awareness* obtained among the members of an organization, inferred from the proportion of correct answers given on all four questions by the members of an organization and (d) the *working process*, inferred as a qualitative assessment on (1) how the information is accessed and shared, and (2) pattern of communication and decision making within the organization.

Measurements

As per prior experiments based on the ELICIT software, most of the dependent variables can be computed from the Elicit Transaction Log files. The computation taken for each dependent variable is summarized in Table 2 below:

Table 2 - Computations made for each of the dependent variables

Dependent Variable	Experimented C2 Concept		
	Traditional Hierarchy	Hybrid	Edge
Decision Speed	Time taken for Cross Team Leader to decide	Time taken for 3 or more among the leader group to agree on solution	Time taken for 9 or more in the whole organization to agree on solution
Organizational Decision Accuracy	Solution posed by Cross Team Leader	Solution arrived by consensus (3 or more agree) between leaders	Solution arrived by consensus (9 or more agree)
Level of Correct Shared Awareness	Proportion of Org with 100% correct answers	Proportion of Org with 100% correct answers	Proportion of Org with 100% correct answers

In addition, context of the detailed CHAT activities by each team during the experiment can be obtained from the Log files from the Chat-rooms. Lastly, analysts were stationed to monitor and note down observations for each team during the conduct of the experiments.

Statistical analysis

Statistical analyses were performed through STATISTICA 7.0. (www.statsoft.com). All variables were checked for normal distribution and the correlation (Pearson r) between them were computed. We also computed mean values and standard deviations for the outcome of the three dependent variables, organizational decision accuracy, decision speed, and level of shared awareness for each condition (TH, HY and E). Based on mean values and standard deviations we calculated the effect size index, Cohen’s *d* (Cohen, 1977). We did not apply significance testing of the differences between mean values because there were too few observations (two teams) in each condition. Because of few observations there is uncertainty regarding the true value of the standard deviations, and the computation of the effect size, thus these statistics should be interpreted with some caution.

EXPERIMENT RESULTS

Results for Dependent Variables

The results for the dependent variables were summarized in Table 3 below.

Table 3 - Individual team results on three of the dependent variables

C2 Concept	Organizational Decision Accuracy (Correct / Incorrect)	Decision Speed (Minutes)	Shared Awareness (Proportion of Org with 100% correct answers out of 17)
Hierarchy	Incorrect	41	6
Hierarchy	Correct	44	1
Edge	Correct	36	16
Edge	Incorrect	35	0
Edge	Correct	25	15
Hybrid	Incorrect	36	0
Hybrid	Correct	41	8

Outliers

One of the teams in the Edge condition (indicated as a shaded entry) did not follow the instructions completely. In the after-action review performed after the training run, the team members decided that they preferred to have some structure in their Edge run so they appointed the same player who had acted as cross team coordinator in the training run to perform a similar function also in the edge run. The appointment of a leader before the game had started meant that the team had removed a major part of the collective responsibility as an inherent Edge trait as well as the ability for emergent control behavior to occur. The team was therefore not operating as an Edge organization the way we intended. We decided to treat that team as an outlier, but we still use this team for some of our qualitative evaluations later in the text.

Correlation between outcome variables

The outcome variable *decision accuracy* is bivariate (*correct* answer on the four questions or *incorrect* answer) and thus not normally distributed. Evaluation of assumptions of normality regarding the outcome variables *decision speed* and *shared awareness* showed that these variables were reasonably normally distributed with skewness and kurtosis less than +2. The correlation between decision speed and shared situation awareness was rather substantial but not statistically significant at the 5%-level ($r = -0.50, p > .05$). Interestingly, the direction of the correlation was negative, suggesting

that the longer time spent on solving the task, the less number of correct assessments among the team members.

Timing and Task Completion

All teams completed the task and submitted an answer before or on time, although some individual players in some teams did not. For the two teams in the traditional hierarchy condition (TH) the average decision time was 42.5 minutes (SD = 2.12). For the hybrid between hierarchy and edge organization condition (HY) the mean value of decision time was 38.5 minutes (SD = 3.53). For the edge organization condition (E) the mean value was 30.5 minutes (SD = 6.73), and the mean value for all conditions was 37.2 minutes. Thus, the difference between the TH and HY is 4 minutes; the difference between the E and the HY is 8 minutes, and the difference between the TH and the E is 12 minutes which means that the teams in the TH condition on average used more than 25% longer time to make a decision than did the teams in the E. The difference is substantial and this is reflected in the effect size index: Cohen's $d = 2.10$; a d larger than 0.8 is regarded as a large effect size (Cohen, 1977). Also the differences in decision times between the E and the HY and between the TH and the HY are quite substantial as indicated by effect size indexes over 1.3. These results indicate that the fastest organization to make a decision was the edge, followed by the hybrid and the slowest was the traditional hierarchy. This result is contrary to our expectations, and it suggests that the need to seek a majority consensus that we imposed on the teams in the E condition (and also, but to a lesser degree, on the teams in the HY) did not slow them substantially. Our results are thus in line with earlier results (Lewelling & Nissen, 2007) demonstrating that the edge performed faster than the traditional hierarchy.

Organizational decision accuracy

In the edge condition both teams made correct majority decisions (i.e. at least nine players agreed on a common assessment on all four questions). In the HY and the TH one of two teams in each condition made correct decisions. If a correct answer is scored as 1 and a wrong answer is scored as 0, this gives a mean value of 2.0 (SD = 0.0) for the E and mean values of 1.5 (SD = 0.7) for both TH and HY. The effect size index is 1.01,

indicating a large effect. The result suggests that the teams in the edge condition had higher organizational decision accuracy than did teams in TH and HY, but the latter two teams performed equally good/poor in this respect.

Level of Shared Awareness

In the edge condition the average number of team members who submitted correct assessments on all four questions (who, what, where and when) was 15.5 (SD = 0.7) or 91 %. The corresponding figures for the HY was 4.0 (SD = 5.65) or 23.5 %, and for the TH it was 3.5 (SD = 3.53) or 20.5 %. The effect size index indicates a small effect between the TH and the HY but a large effect both between the TH and E (Cohen's $d = 4.72$) and between the HY and E (Cohen's $d = 2.86$). The result suggests that the teams in the edge had a high level of shared *correct* awareness of the threat situation, and also considerably higher than did teams in both of the other conditions. The difference between teams in TH and HY was unsubstantial, suggesting that these two types of organizations perform equally well/poor regarding the ability among the members of the organization to reach a high level of shared, correct, awareness. All these three main results of the dependent variables are in favor of the edge organization. But before we discuss the reliability and validity of the results we will provide a more detailed description of how the teams in the different conditions actually performed as this will make it easier to understand why some of the differences in the outcome variables explained above occurred.

Detailed Observations for Traditional Hierarchy Runs

Using the PAJEK software, network diagrams of the "SHARE" traffic for each team experimenting with the TH concept were obtained. Figure 1 presented the linkages that resulted from the "SHARE" traffic in both TH runs. This illustrated the lack of active sharing as some members of the organization were clearly missing from the network and were hence not sharing factoids with other players in the organization. The thicker lines represented some active sharing between certain members. We therefore observe variance in the participants' propensity to contribute towards common availability of information within the organization.

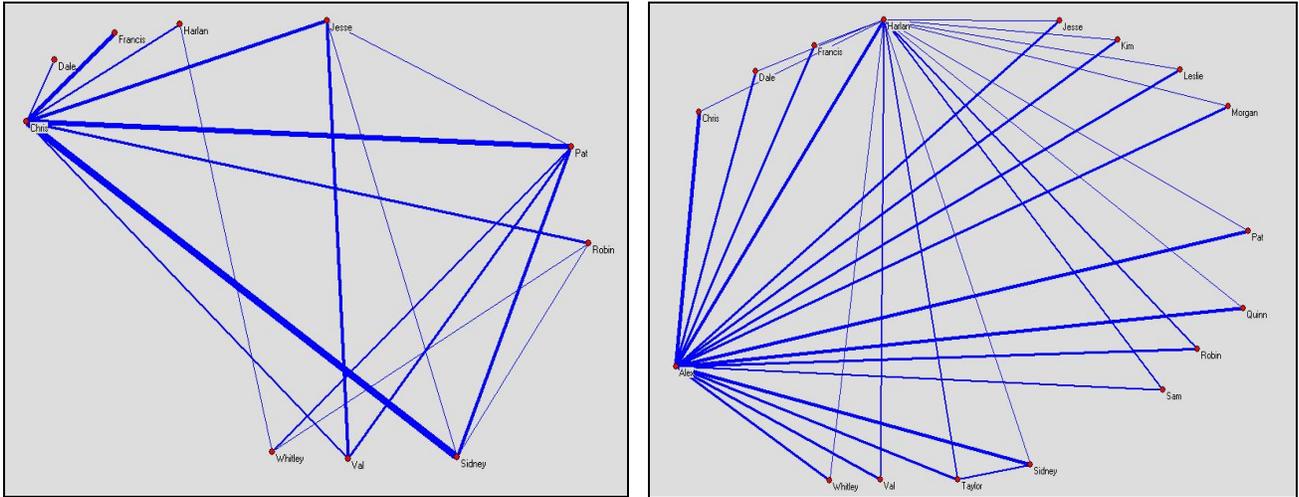


Figure 1 - The SHARE diagrams for both teams under TH concepts.

A detailed look at the breakdown of individual answers showed that the “Where” teams in both runs had difficulty identifying the answer to the “Where” task (see Table 4). The first team that experimented on the TH concept did not manage to give the correct answer for the “where” part of the solution. It was observed that 2 out of 3 members in the “Where” task got it correct, the “Where” team leader did not accept the answer and hence was unable to provide a correct answer to the Cross Team Leader. This effect corresponded to the first plot in Figure 1 where some members were missing from the SHARE network and did not disseminate their factoids. Therefore the Cross Team Leader was not able to analyze all factoids to derive his own answer. Interestingly, we noticed that the second team only managed to give the correct answer because the Cross Team leader worked on the analysis himself and proposed the overall solution instead as he was not able to obtain confirmed solutions from the team leaders.

Table 4 - Individual team members results on the threat identification task.

C2 Concept	Organizational Decision Accuracy (Correct / Incorrect)	Decision Speed (Minutes)	Proportion of Org with 100% correct answers (out of 17)	Team Members (M) and Leaders (L) who got their task correct							
				Who		What		Where		When	
				M	L	M	L	M	L	M	L
Hierarchy	Incorrect	41	6	3	1	3	1	2	0	3	1
Hierarchy	Correct	44	1	3	0	3	0	2	0	2	1

Detailed Observations for Hybrid Runs

We discovered that the availability of common websites resulted in most players using “POST” rather than “SHARE” actions, resulting in very minimal “SHARE” traffic under the Hybrid runs and hence no analysis was conducted on this aspect. A detailed look at the breakdown of individual answers showed that the two teams experimenting on the Hybrid concept had very different outcomes (see Table 5). A detailed examination of the factoid dissemination showed that one of the members in the first team did not post a critical factoid on the websites and hence no one else in the organization had access to this piece of information. Hence all analysis and deductions made by the members and leaders led to the wrong conclusions and the entire organization reached a consensus but on the wrong answer. The second team managed to achieve good dissemination of the factoids and hence was able to arrive at the correct answer.

Table 5 - Individual team members results on the threat identification task.

C2 Concept	Organizational Decision Accuracy (Correct / Incorrect)	Decision Speed (Minutes)	Proportion of Org with 100% correct answers (out of 17)	Team Members (M) and Leaders (L) who got their task correct							
				Who		What		Where		When	
				M	L	M	L	M	L	M	L
Hybrid	Incorrect	36	0	3	0	1	0	0	0	0	0
Hybrid	Correct	41	8	3	1	2	1	3	1	1	1

Detailed Observations for Edge Runs

As mentioned in the earlier analysis, the team that did not perform the experiment according the instructions was identified as an outlier and was not included in this analysis. A detailed look at the breakdown of individual answers showed that the two teams experimenting on the Edge concept had similar outcomes (see Table 6). A detailed examination of the factoid dissemination showed that all critical factoids were disseminated and hence everyone in the organization had access to all information. It is also interesting to note that the decision making by consensus leveled up almost everyone in both runs to the complete answer. However, an unexpected observation was made in both runs: after an initial stage of level playing field, some form of leadership emerged. Evidences from the Chat Log showed that Kim for the first team and Leslie for the second team emerged as eventual leaders who consolidated the solutions based on consensus building and concluded the runs.

Table 6 - Individual team members results on the threat identification task.

C2 Concept	Organizational Decision Accuracy (Correct / Incorrect)	Decision Speed (Minutes)	Proportion of Org with 100% correct answers (out of 17)
Edge	Correct	36	16
Edge	Correct	25	15

Detailed Observations for Outlier Data Point

Apart from the fact the team did not intentionally participate as an Edge organization, the detailed observations also revealed interesting findings. One such observation showed that the team did not perform well partly due to incomplete dissemination of critical factoids, which was due to inactive posting of factoids by certain members of the organization. This was also the main factor affecting non-performing run under the HY cases.

DISCUSSION OF FINDINGS

The main findings from this study was that on this task, when an intelligence organization have to analyze incoming data and decide on an interpretation of these data, **the edge organization outperformed both the traditional three-level hierarchy and the hybrid edge/hierarchy organization on decision speed, decision accuracy and level of shared, correct, awareness of the threat situation. The hybrid organization made decisions faster than the traditional hierarchy, but performed equally well on decision accuracy and shared awareness among the members of the organization.** The main reason behind the difference between the edge and both of the hierarchies (the HY is also a kind of hierarchy) is probably that in the hierarchy the processing of information takes place at two different levels subsequent to each other in time, but in the edge there is only one processing level. In the hierarchy there is first some processing within the functional team (e.g. the who-team). This processing involves the team members and their team leader. Next, there is a second sequence of processing, involving the team leaders for all four teams and the cross team coordinator, (i.e. the commander). This takes time and moreover, we saw examples how the team-leaders did not share the threat evaluation made by their team members and thus did not report the team evaluation

to the cross team coordinator but only their individual assessment, resulting in the command team getting it wrong while the functional team had the correct assessment.

An interesting finding that was unexpected was the **emergent leadership roles that certain members took up as the Edge runs progressed**. This may highlight the need for certain leadership and hierarchical structure (however flat this may be) in order for Edge organizations to collaborate and perform decision making via consensus. Although not conclusive in nature, this may provide indications that some form of leadership and structure may still be required should coalition forces and non-hierarchical organizations need to function and operate in cooperation.

Through detailed analysis of the “SHARE” and “POST” traffic, we noticed that **regardless of the organizational concept, there were always players who had a higher propensity to share information and vice versa**. Hence it may be relevant to ask questions about the effect of organizational culture and behaviour on organizational performance, which may or may not be an overriding factor as compared to the organizational structure itself. Or perhaps recognizing that it may be highly unlikely to achieve perfect organizational culture and behaviour, it would be interesting to identify structures and concepts that are most robust against such variability.

CONCLUSION

In our concluding segment, we would like to discuss issues pertaining to reliability and validity of our results. Firstly, as the number of observations is small, at only two data points per condition, this makes it difficult to establish how stable these results will be if the study was to be replicated. Secondly, as has been shown from the qualitative analysis of the information dissemination traffic, a key factor for success in ELICIT, regardless of organizational structure, is that all (critical) information received by a player gets posted on a website so that more people can take account of it. This depends on the individual player's behaviour during the experiment and may not be attributed to any particular C2 structure. Having insufficient runs to average out this uncontrollable variance may have distorted the total results.

Another issue related to the reliability of the results is that the ELICIT game seems to be weak in the representation of coordinating information flow, which is an essential strength of a hierarchical organization as the leader can always decide that he did not have enough information and demand his subordinates to provide more sharing of information. This missing portion of the representation of the hierarchical organization could bias the results in favor of the Edge.

To address validity, we would like to discuss whether the results from this study can be generalized to real C2 organizations. We showed that in at least some circumstances consensus decision making in a flat organization does not have to take longer time than hierarchical decision making, at least not in a situation where a true, or objectively correct, decision can be found. On the contrary, it can be faster. We also showed that filtering of information through hierarchical “filters” is risky and sensitive to distortion in some cases. Some mid-level managers can suppress the opinion of their subordinate team members and present only their own personal view, and there is normally little incentive for a superior commander to surpass his subordinate commander and go directly to the team in order to get their view. We also showed that understanding of the intent, however simple it may be, (in this case to answer four different questions), is not enough. It is equally important for success that the individual entities of an organization (a) understands its own role (here to disseminate incoming information) and (b) that there is a functional working procedure in the organization so that all team members can contribute effectively (c.f. Jensen, 2006). Although may not be statistically robust, these findings do possess a fair amount of face validity.

Another issue is of course if an edge C2 organization generally would outperform a hierarchical C2 organization regarding decision speed, decision accuracy and level of shared (correct) situation awareness? This can not be concluded from our results, partly because of the reliability issues related previously, but mainly because the differences between the ELICIT and a real C2 organization are substantial. First, an organization normally have to take some action and not only perform a decision as in ELICIT. In real C2 situations this need for action often requires some prioritizing of resources as well as determine the order that the actions are taken. This might be quite difficult and time consuming in a flat organization. Second, in real C2 situations no objectively correct

“truth” can ever be found, as in ELICIT. It is always a matter of opinion among the members of the organization how a specific task and situation should be interpreted and real values are at stake, which make people more prone to fight for their beliefs. This is also a complicating factor for a flat organization. Third, in real C2 situations, the participants tend to have different level of experience and background, which makes them less able to act as equals in a flat organization.

These are all problems that cannot be addressed through ELICIT experiments, but requires another and more realistic platform. However, ELICIT may still be a platform for experiments regarding how representatives of different organizations come to consensus, and it would also be interesting to analyze further how leadership within the edge organization emerges spontaneously, and which individuals will step forward and take the lead in a team. In this current experiment we also measured individual decision-making styles of the participants and we plan to evaluate this further in order to find out if the emergent leaders of the edge teams also have a common decision making style. This however will be presented in a later report.

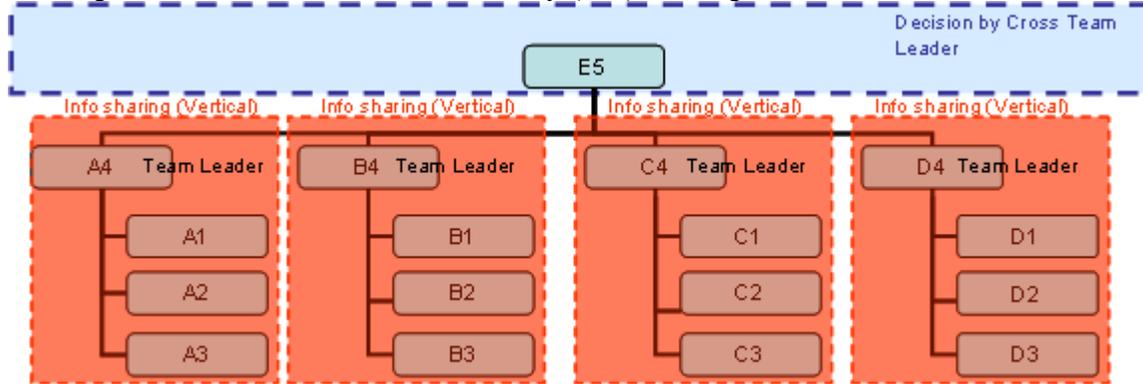
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EXPERIMENTATION MATERIALS

Description of the Traditional Hierarchy (TH) Concept



C2 Features:

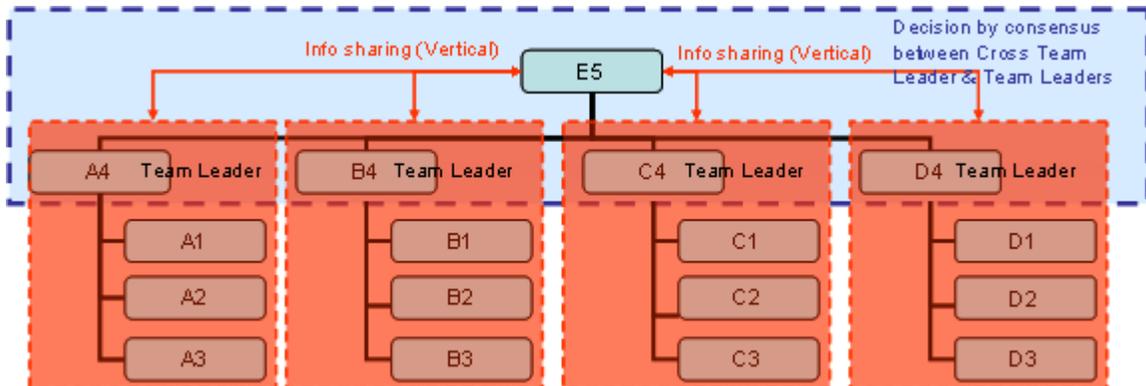
No. of Layers	Three: Cross Team Leader, Team Leader, Team Member
Grouping	Organised in Functional Groups: Who, What, Where, When
Information Access	Access to websites of OWN functional group
Communication Channels through CHAT	Members can CHAT with Members. Members can CHAT with their own Team Leader. Team Leaders can CHAT with other Team Leaders and Cross Team Leader. Members cannot CHAT with Cross Team Leader.
Decision Making	Only by Cross Team Leader

Briefing Instructions:

Item	Instructions
Grouping	<ul style="list-style-type: none"> There will be 4 functional groups. Each person will be assigned to a functional group as either leader or members. There is a cross-team leader on top of the 4 functional groups.
Info Access	<ul style="list-style-type: none"> Each member and team leader have access his OWN functional websites only Cross-team Leader has access to all functional websites.
Communication Channels through CHAT	<ul style="list-style-type: none"> Each member can communicate with his OWN team member and OWN team leader through the respective WHO/WHAT/WHERE/WHEN chat room. Each member can also communicate with members of other functional groups through MEMBER chat room. Each team leader can communicate with team leaders of other functional groups and the cross-team leader through TEAM

Item	Instructions
	LEADER-CROSS TEAM LEADER chat room.
Decision Making Process	<ul style="list-style-type: none"> ▪ Final answer to be decided by Cross-Team Leader. ▪ When Cross-Team Leader has submitted the final answer, Controller will ask everyone to submit whatever answers they feel are correct.

Description of the Hybrid (HY) Concept



C2 Features:

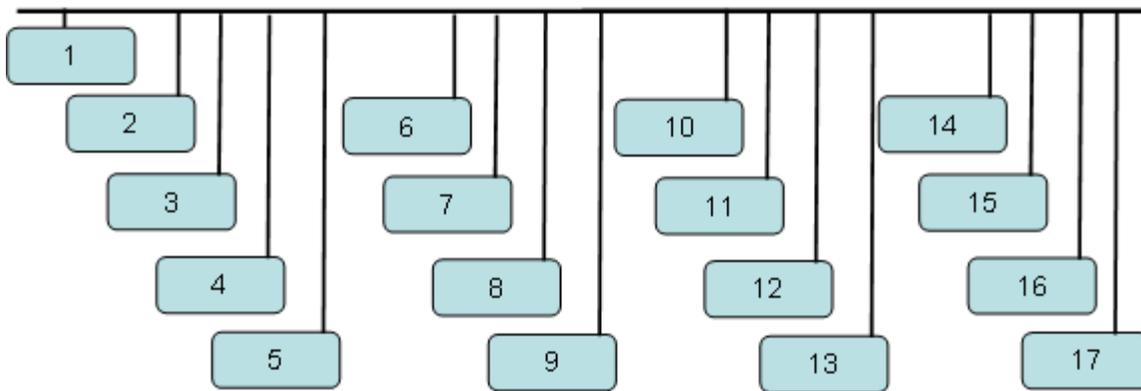
No. of Layers	Three: Cross Team Leader, Team Leader, Team Member
Grouping	Organised in Functional Groups: Who, What, Where, When
Information Access	Access to ALL FOUR functional websites
Communication Channels through CHAT	Everyone can CHAT with everyone else.
Decision Making	Consensus by Cross Team Leader with Team Leaders

Briefing Instructions:

Item	Instructions
Grouping	<ul style="list-style-type: none"> ▪ There will be 4 functional groups. ▪ Each person will be assigned to a functional group as either leader or members. ▪ There is a cross-team leader on top of the 4 functional groups.
Info Access	<ul style="list-style-type: none"> ▪ Each member and team leader have access ALL functional websites. ▪ Cross-team Leader has access to ALL functional websites.
Communication Channels through CHAT	<ul style="list-style-type: none"> ▪ Each member can communicate with his OWN team member and OWN team leader through the respective WHO/WHAT/WHERE/WHEN chat room.

Item	Instructions
	<ul style="list-style-type: none"> ▪ Each member can also communicate with members of other functional groups PLUS the cross-team leader through MEMBER chat room. ▪ Each team leader can communicate with team leaders of other functional groups and the cross-team leader through TEAM LEADER-CROSS TEAM LEADER chat room.
Decision Making Process	<ul style="list-style-type: none"> ▪ Final answer to be decided by consensus among leaders, ie. 3 leaders out of 5 leaders/cross-team leader. ▪ If any leader thinks he has the correct answer, he should seek 2 more consents from the other leaders. ▪ If he obtains a total at least 3 consents including himself, he should inform the other leaders that he has sufficient majority and seek support to submit the final decision. ▪ If he obtains at least 3 supports, he should submit the answer. ▪ When the final answer is submitted, Controller will ask everyone to submit whatever answers they feel are correct.

Description of the Edge (E) Concept



C2 Features:

No. of Layers	One layer for all
Grouping	Nil
Information Access	Access to ALL FOUR functional websites
Communication Channels through CHAT	Everyone can CHAT with everyone else.
Decision Making	Consensus by all members

Briefing Instructions:

Item	Instructions
Grouping	<ul style="list-style-type: none"> ▪ There will be NO functional groups and leaders. ▪ Everyone is a member. ▪ Each member is free to choose to work on any one or more areas.
Info Access	<ul style="list-style-type: none"> ▪ Each member have access ALL functional websites.
Communication Channels through CHAT	<ul style="list-style-type: none"> ▪ Each member can communicate with any member through the COMMON chat room.
Decision Making Process	<ul style="list-style-type: none"> ▪ Final answer to be decided by MAJORITY among members, ie. 9 out of 17 members. ▪ If any member thinks he has the correct answer, he should seek 8 more consents from the 16 other members. ▪ If he obtains a total at least 9 consents including himself, he should inform the rest that he has sufficient majority and seek support to submit the final decision. ▪ If he obtains at least 9 supports, he should submit the answer. ▪ When the final answer is submitted, Controller will ask everyone to submit whatever answers they feel are correct.

Description of Experiment Procedure

Programme for conduct of experiment:

Item	Description
Introduction Brief	Participants were given a description of the 3 experimented C2 concepts, ie Edge, Traditional Hierarchy and Hybrid.
Introduction to ELICIT and CHAT	Participants were given a hands-on training of the ELICIT game and the CHAT.
Conduct of Training Run	Participants went through a complete run using one of the 3 experimented C2 concepts. Each team was given a C2 concept that would be different from the concept that the team would be adopting in the Actual Run. The intention was to allow participants the opportunity to familiarise with the ELICIT game and CHAT functionalities through an actual complete run without getting too proficient with the C2 concept. By doing this, we hoped to removed the time taken for the participants to familiarise on the ELICIT game and CHAT functionalities in the Actual run.

Item	Description
Briefing of Actual Run	The C2 concept that each team was suppose to adopt in the Actual Run was revealed. The teams were also reminded of the details of the structure and C2 features, complete with the instructions.
Conduct of Actual Run	All teams completed their run using the same scenario in ELICIT, but the scenario was a different one from the training run. Controllers were positioned to observe the development of discussions in CHAT and the behaviour of the participants during the runs. Each run was terminated when the final answer was submitted and each player had submitted their own understanding of the answer.

Assignment of C2 concepts to teams:

Team	1	2	3	4	5	6	7
Training Run	TH	HY	TH	E	TH	E	HY
Actual Run	E	E	HY	HY	E	TH	TH