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Edge Organization: Testing a New C2 Model of Battlefield Information Sharing and Coordination

Topic: 3 Information Sharing and Collaboration Processes and Behaviors

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Abstract

Singapore and Sweden have an ongoing collaboration regarding C2 concepts and methods. The purpose of this study was to explore a new process of sharing battlefield information between units in a military C2 structure. The process, called Non-Hierarchical Information Management (NHIM) is an attempt to break barriers emanating from a traditional hierarchical C2 structure that impedes timely sharing between tactical units on the battlefield. NHIM prescribes that all information should be shared in a timely manner and updated in a way similar to Wikipedia, without compromising on mission security. NHIM was supported by enabling C2 collaboration systems and procedures to encourage self-synchronization among forces. SAF and SwAF committed a Brigade staff and three Battalion staffs as participants in two different experimental conditions; NHIM and HIM (similar to current military hierarchical procedure on information sharing). The scenarios included both combat and humanitarian relief operations. Under NHIM condition, key findings were discovered namely; (1) NHIM had led to a higher degree of self-synchronization resulting in a shorter overall decision cycle on the battlefield without compromising on quality of orders and actions, and (2) creating capacity in terms of focused attention and quality time for the Brigade staff to plan ahead.

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Introduction

Background

As in other military armed forces, there are two important trends affecting current command and control (C2) development in the Swedish and the Singapore Armed Forces. The first trend is the increasing capacity of the information technology (sensors, network and computers) and the second trend is the complexity of battlefield situation that results in dynamic changes to missions given to military forces, for example as in Afghanistan and in Iraq. The attendant challenge to developers of C2 models is to exploit information technology for C2 functions to adapt to the changing battlefield conditions.

Sweden and Singapore have an ongoing collaboration aimed at developing and testing new C2 concepts and methods. Previous joint studies between the two armed forces had focused on integrated mission planning. (e.g. Cheah, Thunholm, Chew, Wikberg, Andersson & Danielsson, 2005; Thunholm, Cheah, Fong, Tee, Chew & Larsson, 2006) In another joint study, both sides explored and compared relative advantage on C2 structure between edge organization and traditional C2 organization in a laboratory environment (Ng, Thunholm, Cheah, Tan, Chua & Chua, 2007). The aim for this study was to implement a new concept of edge C2 organization in a more realistic military C2 experimentation setting. The concept will be described in greater details in this paper, but first, some background on this new C2 concept.

The Changing Battlefield

Military commanders are increasingly finding themselves operating in a complex environment. Examples that illustrated the impact of this change on the battlefield and its mission were concepts such as *War Amongst the People* (WAP; Smith, 2006) and *4-block War* (Rudd, Bayley & Petruczynik, 2006). These concepts implied that it is no longer enough for a military commander to be able to defeat another conventional opposing force on the battlefield. The modern commander must be able to conduct broad spectrum operations ranging from humanitarian relief, peace support and peace-keeping operations, combat operations and intelligence and information operations. The purpose is not only to win the war but also to win the peace (Rudd, Bayley & Petruczynik, 2006). Compounding the problem is the need to operate against an opponent that will act as an irregular force, dispersed over large areas, hiding among civilian structures, with no clear force structure that can be localized easily and attacked, and using irregular weapons such as IED and suicide bombers (Smith, 2006).

In the new environment, such changes in the battlefield have several implications on military operations. Apart from the need to operate over a much greater area than before, power must also be distributed to the edge (i.e. tactical) units. Increasingly, military commanders must be adaptive to the changing circumstances both in terms of their ability to detect changes and the agility to mount quick responses. They must also be decisive at the lowest echelon. This meant delegating authorities and having clear but robust Rules of Engagement.

Whilst allowing freedom to improvise at the lowest echelon, Commanders at all levels must be fully aware of the implications of each action. Local commanders have to be aware of developments beyond their area of operations and understanding how it is contributing to higher echelon's objectives and how one's actions may impact on other stakeholders' objectives. Information therefore is of central importance.

One basic assumption from current C2 literature (e.g. Alberts, Garstka & Stein, 1999; Alberts & Hayes, 2005) is that an increased in information sharing among the entities on the battlefield will result in increased shared situation awareness (SSA), for example among different subunits of a deployed Brigade. A high level of SSA will enable faster and more (self-) synchronized actions taken on the battlefield in order to deal with rapidly unfolding events. Faster and more synchronized response are therefore necessary in order to increase the overall mission effectiveness on the battlefield (see Figure 1). This meant that shared understanding and self-synchronization between lower echelon units must be available in a distributed and/or expeditionary operation. This hypothesis is sometimes called the "tenets of Network Centric Operations (NCO)" or "the value chain of NCO" (Alberts and Hayes, 2005; 2006).

Self-synchronization as a C2 concept is not yet fully understood (Alberts & Hayes, 2005). In its purest form it suggests a completely flat organization, but this is not how we define it in the context of our experiment. Instead of *total* self-synchronization, we used *increased* self-synchronization as comparison to the traditional hierarchical system where all coordinations in principle had to be done by a higher HQ. Thus we encouraged self-synchronization between units at the same level with guidance from Higher HQ such as commander's intent and tasking to the subordinated units. Earlier findings on self-synchronization in micro-world C2 of fire-fighting (Brehmer, 2009; Brehmer & Svenmarck, 1995) indicated that (1) in order for self-sync to take place, there must be a learned procedure on how to do it. It is not enough to provide (relevant) battle-field information such as blue force tracking and a common operational picture. The staffs must also be trained in the new self-sync procedure. (2) Self-sync occurs along boundaries between equal level units; both physical boundaries and overlapping tasks. (3) For self-sync to be effective, the synchronizing parties must have a shared opinion regarding the common goal and intentions as issued from a higher commander. The parties also need to be in control of resources necessary for synchronization to take meaningful effect. For example, if unit A needs to support unit B with fires, unit A needs to have control over some artillery unit. (4) Self-sync must be done at the right time, i.e. self-sync between battalions (Bns) must take into consideration that it will take some time before orders from the Bn can be effectuated on the battlefield, thus, self-sync between Bns refers to actions in the future and not for the convenience of immediate situation.

A New C2 concept: Non-Hierarchical Information Management

Non-Hierarchical Information Management (NHIM) is a concept developed by the Swedish Armed Forces (SwAF) Joint CD&E Center. The NHIM concept is connected to the value chain of NCO or NEC3 (Networking Enabled Command, Control and Communications) as it is called in SwAF. In Figure 1 NHIM's connection to the Value Chain of NCO is presented.

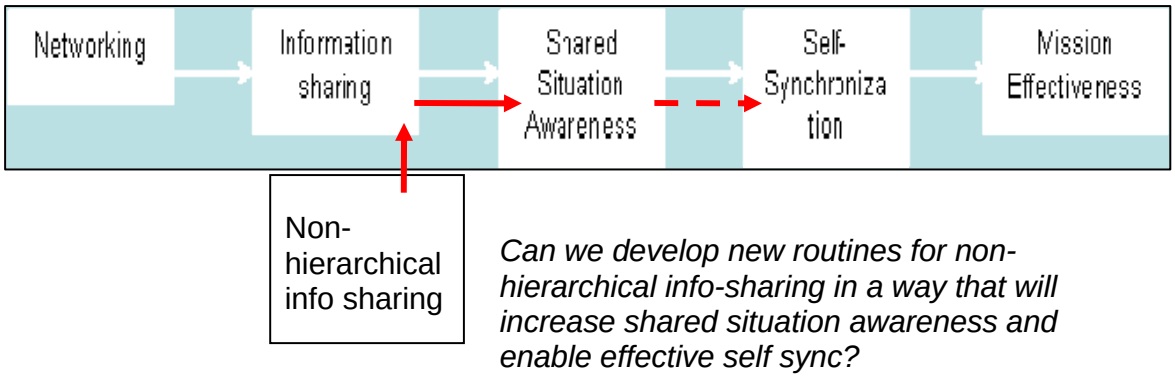

Figure 1. *The NHIM concept in relation to the Value Chain of NCO.*

The core conceptual thinking of NHIM is that the information available within a C2 structure in principle should be accessible to all members of the organization. All members (units) in a C2 structure should also be able to update information in ways similar to how Wikipedia is updated, and the situation picture should be common and accessible. (However this does not preclude exception to the rule such as when mission security and originality of source needs to be protected. Also NHIM recognizes that different levels may have different needs for details of the situation as well as geographical needs). Differences in opinion between units regarding map objects should be resolved at the level where they occurred, but a higher hierarchical level with a better overview of the whole situation should also be able to give guidance regarding how to interpret ambiguous information (i.e. higher staffs must still conduct situation analysis and provide intelligence summaries, and estimates to subordinates).

NHIM is also in line with the idea that the battlefield environment is highly dynamic with a high demand of synchronizing local objectives with higher strategic goals. In addition, a common reference picture as provided through the NHIM procedure is supposed to reduce ambiguity. Building a common reference picture will thus reduce ambiguity and improve shared understanding across the organization. This in turn will enable collaboration and synchronization between side-ordered units without involving HHQ unnecessarily. This means enhanced performance in terms of coordinated and effective actions, combined effects, agility and avoiding fratricide. The idea of horizontal coordination (i.e. self-synchronization) is not an explicit part of the SwAF NHIM concept, but as NHIM is an enabler for such coordination, we included rules on how to conduct self-synchronization in the NHIM concept for this experiment.

As shown in Figure 1, NHIM deals directly with the way information is being managed in the C2 chain, and the direct purpose of NHIM is to increase the level of shared situation awareness of members within a C2 structure whilst enabling horizontal coordination among same-level of units in a C2 structure. This experiment was designed to evaluate both of these two aspects. A detailed description of how the NHIM concept was operationalized in this experiment is provided in the method section.

Problem Statement

According to the Value Chain of NCO (Figure 1), the first step in the chain towards mission accomplishment and mission effectiveness is to enable more sharing of battlefield information among different units operating on the battlefield. Take for example a Bde structure; today Bns send situation reports (sitreps) to the Brigade (Bde) HQ. The Bde Staff will analyze and add reported information to their situation map (sitmap). All HQs will have, and update, their own sitmap, independent of each other. The Bde will send (master-) sitreps or intelligence summaries regularly to subordinates. Given modern C2 technology, we think

that current system is not optimized to develop a high level of SSA among different units and that it is time consuming for the Bde to analyze and understand the current situation (i.e. "Now-casting). Instead we envisaged that in the future, the use of modern collaborative C2 systems will make it possible for all units to actually have access to the same sitmap. (e.g. a certain layer/overlay in the collaborative C2 system can be devoted to "common blue force sit" and another overlay can be "enemy sit"). Subordinated battalions (Bns) can then update the "common" sitmap (and add comments) instead of sending sitreps to the Bde. As a result of this shared sitmap and the ability to communicate among units in the C2 network as if they were all co-located and looking at the same map with the ability to increase effective self-synchronization between Bns. The key interesting questions are: *Will such a change in collaboration routines, indating routines and access to a common sitmap increase Shared Situation Awarenes, increase the Bde staff's attention to future events (as opposed to spending time on now-casting)? Similarly will it shorten the reaction time to implement actions on the battlefield, (given that the right to self-synchronize are given to the Bns)?* These are the specific research questions that we are addressing during this experiment.

Expectations

Building on the ideas regarding the new battlefield and on the current C2 theory as presented in the previous section, we developed some expectations regarding positive effects of NHIM for the C2 function of a military organization.

We expected the (positive) *effects* of NHIM (as compared to Hierarchical Information Management, HIM, which was the condition we used for a comparison in this experiment) in a two-level military hierarchy (e.g. Bn – Bde) to be as follows:

- A higher level of *shared* SA. This expectation was based on the fact that through the NHIM procedure, the lower levels would also have full access to the situation picture and the reports of the Bde and that all other units as defined under the NHIM condition, such as the Bns will also need to share more information in order to be able to self-coordinate their actions with each other.
- Faster and more responsive synchronization of blue actions on the battlefield. This expectation was based on the fact that with our definition of NHIM, lower level (ie, Bns) is therefore given the rights/permission to coordinate and share information directly (timely) among themselves. Also, with NHIM, the lower level (Bn) would have access to the same sitmap as the Bde and thus be able to anticipate (and effectuate) possible coordination with side-ordered units as battlefield situation developed, as opposed to receiving scheduled (and delayed) intelligence summaries from HHQ in a HIM procedure. This meant that we also expected relatively more communication between Bns in NHIM than in HIM.
- Good quality in self-coordinated actions and orders issued. Although we recognize a risk that self-coordination among lower levels units would sometimes result in actions less well aligned with the higher commander's long-term intent, we would still expect commanders on lower levels to overcome this difficulty and generally be able to come up with proper actions and orders from the point of view of the higher commander. Thus, our expectation was that the quality of orders issued by the Bns would be equally good in NHIM as in HIM.
- The higher HQ should be less actively involved in coordination of current activities between the Bns and also in compiling reports and assessing the current situation. This should create capacity and mental resources that we had expected for use in forward planning at later phases of the operations. This expectation is based on the fact that higher HQ needed to spend less time on receiving and transforming sitreps from subordinates to sitmap information. Instead they would be provided with a detailed

Method

Participants

The organization of the participants is shown in Figure 2. In total 13 army officers participated. From Singapore six officers from the SAF 7th Brigade participated. The Bde Commander, the Bde S2 (Intelligence) and S3 (Current Operations) officers role played the same roles in the fictitious 4th Bde, and the staff was also augmented by a SwAF officer role playing as liaison officer resulting in n = 4. The other three SAF officers role played as Bn Commander (Cdr), S2 and S3 officers of the fictitious 443rd Bn. Mechanized Bn (n = 3), which were similar positions as they held in the SAF 7th Bde.

From SwAF six army officers from different SwAF regiments role played as Bn Cdr, S2 and S3 in the fictitious 158th Infantry Bn (n = 3) and 42nd Mechanized Bn (n = 3).

All participants were male and between 29 and 50 years of age (M = 39 years). Participants had between 10 and 30 years in service in the armed forces (M = 18 years) and held the ranks of Colonel (n=1), Major (n=8) and Captain (n=4). Participants varied in specific military occupation. In general the Singaporean officers had training as Guardsmen and not as officers in mechanized units. However, in the experiment they acted in positions similar to their current positions within SAF. Most of the Swedish officers had a background in mechanized units, but only few of them had previous experience from the exact position they held during the experiment.

The overall conclusion based on the level of experience of the participating officers was that they were well suited to perform adequately in their assigned roles in the experiment and should not limit the ability to generalize the results. The participants were informed of the two different experimental conditions in advance but not of the dependent variables or the expectations/hypotheses.

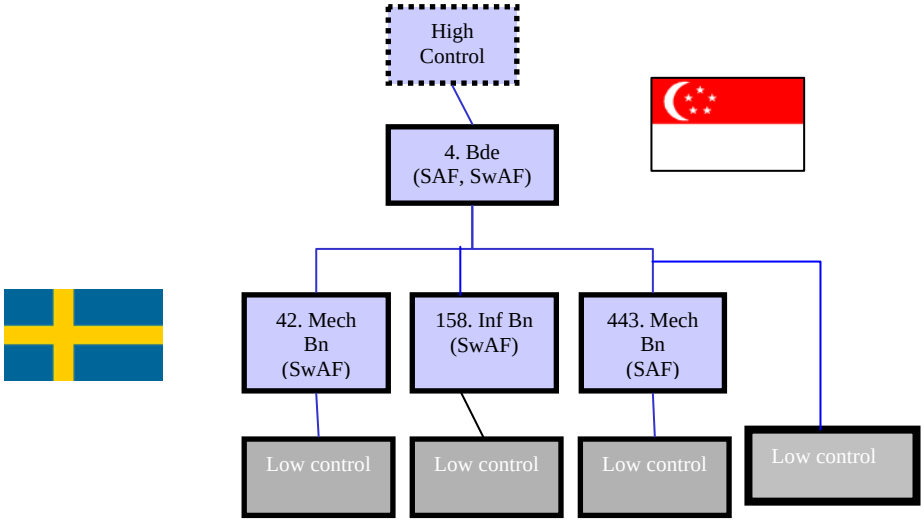

Figure 2. *The Order of Battle (ORBAT) used in the experiment.*

Scenario

The scenario was developed by military subject matter experts from the Singapore Armed Forces Centre for Military Experimentation (SCME) and the Singapore Army. The scenario

was basically a traditional ground combat scenario, including several elements of civilian activities that affected the conduct of operations. A more detailed description of the scenario is provided in Appendix 2.

The scenario play was continuous, but we run it divided in eight three-hour runs over four days. All runs included events that should force reactions and development of new Fragos from the participants and Run 2 started where Run 1 had ended and so on. Run 0-2 were training runs executed in the NHIM condition and Run 3-4 were experimental NHIM runs. Run 5 was a training run for HIM and Run 6-7 were experimental HIM runs. The aim was to have the scenario injects for each condition at a comparable level of complexity between the two conditions.

The roles of Division Cdr and staff were fulfilled by members of the High control function and the roles of subordinated units to the Bns (and to some extent also to the Bde) were fulfilled by members of the Low control. Each Bn had all their subordinated companies role played by one officer in the Low control, and the Bde, beside having the Bns as subordinated units, also had all other Bde subordinated units role played by one SAF officer in the Low control.

All units and activities in the scenario were simulated in the ATLAS wargaming system, which also determined the outcomes of all combat events between the opponents in the scenario. The ATLAS system is a time-step constructive simulation system designed to train Bde and Bn levels' Commanders and principal staff officers in decision making and operating procedures in the conduct of land operations employing land, air and naval assets. The experimental physical set-up of systems and locations of units is presented in Appendix 2.

Task

The participants in the experiment were role playing a Bde (consisting of two mechanized and one infantry Bns), The Division operational orders (opord) as well as the Bde opord had been prepared in advance. However, the participants in the Bde were given some time to conduct a plan review and make adjustments to the plan in order to mentally take possession of it before the experiment started. They also issued orders to the Bns as a preparation before the beginning of the scenario play. The task given to the participants was to act in their assigned roles and to the best of their ability executed the orders received from the higher Cdr. They were also instructed to follow the NHIM and HIM procedures closely. The execution process included continuous assessment of the development of the situation, production and distribution of sitreps through the C2 systems, activity coordination and development and issuance of Fragos in response to events that were judged by the participants themselves to require Fragos. A written Frago follows a fixed format (template) and included information regarding the situation (the circumstances motivating a new or adjusted task) and the new or adjusted task itself.

The Mission Mate Command and Control System Application

Mission Mate (MM) is a C2 system designed and developed by SCME to support experimentation. One of the key design features is that it allowed rapid customization to suit new experiment conditions. Another important feature is that it supports map-based collaboration. The key application used to enable the NHIM condition is the Team Operating Picture (TOP). The TOP is an application that enabled GIS-based whiteboarding collaboration and parallel planning operating. The key feature of TOP was the idea called TeamSight, which augmented with other communication tools such as video conferencing and chat, enables distributed Command Teams to co-author a plan together on a virtual map-based whiteboard that would allow members to oversee each other's developments in real-time, facilitate discussions on plans in a distributed mode, and thereby increasing team insight

generation. In TOP both private and common workspaces were available. This meant that staff officers can prepare overlays, e.g. situation updates, in a private workspace and thus making it available to all through the common workspace.

In the HIM condition no collaborative shared workspaces were available, only private workspaces for individual participants. The implication was that in order to share overlays between staffs, participants had to attach overlays to emails and send to the recipient, who could then import to his own workspace. Sharing overlays within a staff could be done by projecting from the own computer onto a wall mounted screen.

Design

The study employed a quasi-experimental, repeated measures design in which participants executed command in two different conditions. *Independent variable* was the C2 model, in two different conditions. The experimental condition was labeled *Non-Hierarchical Information Management* (NHIM) and the control condition was labeled *Hierarchical Information Management* (HIM). Both conditions were defined in terms of (1) the specific organization (a Bde staff and three subordinated Bn staffs), (2) the C2 system we used (Mission Mate, voice/text chat, and email), and (3) the standard operating procedure for sharing information, communicating and coordinating during the execution of a mission in a modern combat operation, with the added complexity of having to deal also with Civil-Military Relations (CMR). In the following sections a description of the NHIM and HIM procedures for information sharing, communication and coordination is provided.

Independent Variable condition 1: The NHIM Condition (experimental)

- *Information sharing*: a) Enemy (Red)/Civilian information, i.e. map symbols and short text explaining/complementing the symbol, was available on the Common Operating Picture (COP) workspace in the Mission Mate Collaborative C2 system (the TOP). This information was updated by unit commanders and staff. Different HQs was required to update situational information within its own boundaries or area of deployment and information coming in from own sensors. However, other blue force units located in the same area also had the right to update Red/Civilian information if they knew that the situation had changed. If a HQ had received Red/Civilian information that was in conflict with information that was already indated in COP by another HQ, they should add the new information on their own workspace so that this information would also appear in COP, but at the same time information the HQ who first indated that same information that there was a conflict regarding this information, so the conflict could be solved. Regarding sitreps, all HQs should email them to all other units.
- *Information sharing:* b) Blue force tracking made all blue force elements available to all staffs in a common blue force situation workspace. A HQ was required to update situational information within its own area of deployment and information coming in from own sensors. Units should not update information about other blue units. (i.e. a HQ should update its own resources but not resources belonging to another blue force unit).
- *Communication:* All commanders were required to listen in to a common Cdrs' chat room (voice and text chat). The same rule applied to all S2 and S3 officers in all units. Thus, all commanders/S2s/S3s could listen in to coordination going on between two or more units within their own function, but it was also possible to invite S2s and S3s to

- *Coordination:* The guiding principle in NHIM was that the coordination on the battlefield should be solved at the Bn level in order to act effectively within the scope of Bde commander's intent. Bn commanders should be aware of adjacent units *and take initiative* to synchronize own actions with other Bns when a good opportunity arise (here good opportunity referred to the ability to take effective action on the battlefield, based on higher Cdr's Intent). Such coordination should be done through video chat/conferencing and through collaborate planning using MM. The basis for self-sync was the COP workspace, blue and red situation overlays. Any Bn commander realizing an opportunity to assist another Bn in order to support overall mission fulfillment was *encouraged* to contact that Bn and propose assistance or collaboration. Any Bn commander who realized a need for assistance with assets belonging to an adjacent Bn was *encouraged* to contact that Bn and request assistance or coordination of assets and efforts. The Bde staff should *encourage* self-coordination between Bns by showing trust and by providing a clear intent and tasks to the Bns. When Bn – Bn synchronization was initiated the Bde staff should be notified. The Bde staff had the ability to enforce hierarchical coordination or prevent self-synchronization if it was deemed necessary based on the overall mission fulfillment.

Independent Variable Condition 2: The HIM Condition (control)

The HIM condition was supposed to be similar to todays' *formal* procedure, except for the adaptation to a different C2 system (MM). The following description of the HIM condition includes only the differences compared to the NHIM condition.

- *Information sharing*: a) For enemy/civilian information all units used their own private workspace in MM for indating of information. This meant that all four HQs were able to access their own private sitmap only. They were unable to access each other's overlays. In order to share overlays, email attachment of an overlay was required. Situation information that could be of interest to other units should be reported through email or VC chat (hierarchically) to the Bde staff. The Bde staff was responsible for assessment and dissemination of situation information to the other Bns.
- *Information sharing:* b) Blue force tracking made only blue force elements belonging to a specific unit available to that staff, i.e. 158 Bn staff had access only to blue force tracking information of their own subordinated companies, while the Bde had access to the tracking of all units in the Bde.
- *Communication:* All commanders/S2s/S3s would use their own unit's chat room. For voice/text chat communications with other units, private chat should be used. However, the Bde could initiate conferences on the common chat rooms if necessary. Emails from one unit to another should not by default include all other units. Basically, all communication was hierarchical, with the Bns communicating with the Bde, although the Bde could initiate shared communication among all units if they found it necessary.
- *Coordination:* The guiding principle in HIM was that the coordination on the battlefield should be done through the Bde staff. Bn Cdrs in need of assistance or synchronization from/with another Bn should express that need to the Bde, and not make contact directly with other Bns. Bn commanders who wanted to use resources belonging to another Bn should *request coordination through the Bde*. Such coordination could be done through video chat/conferencing but not through collaborative planning through the MM C2 system.

Main Differences between the NHIM and the HIM Condition

The main differences between the NHIM and HIM procedures are presented in Table 1.

Table 1. *Differences between the NHIM and HIM conditions.*

Condition	Information sharing (red/civ)	Information sharing (blue)	Communication	Coordination
NHIM	Situation information available to all through a COP workspace. Sitreps distributed to all units.	Blue force tracking of all units available to all in a common blue force overlay.	Cdrs and staff required to listen in to a common chat room (voice and text) and communicate "openly".	Bns should take initiative to self-coordinate when possible. BDE can "veto".
HIM	Situation information is private to each staff. No common COP. Sitreps distributed hierarchically	Blue force tracking of own Bn units only. Only Bde gets full picture.	Communication is private and hierarchical by default. Common chat is an exception.	Coordination of Bn activities should be done by the Bde.

Dependent variables and measurements

Six variables (DV1-DV6) were measured in order to determine the effectiveness of NHIM relative to HIM. In addition the intent was to gather further insights on what procedures that would be necessary to develop further in order to make NHIM operational in a field-setting.

DV1: Shared Situation Awareness has been defined as "the degree to which team members possess the same situation awareness (SA) on shared SA (SSA) requirements." (Jones & Endsley, 1996). In accordance with Endsley (1997) SA was divided into three different levels, SA1-SA3.

Level 1 SA was defined as knowledge of current location of objects such as units present in the situation, i.e. map symbols. After each run, each participant was asked to define the correct location of a set of predefined objects (n=15) on the situation map. The results where then rated based on a sitmap showing the "ground truth" taken from the simulation system at the time that the measurement was taken. Each object was either judged to be correctly or incorrectly positioned. A correct answer generated one score. The scores were then transformed to proportion of correct answers (maximum 100%). The individual level of SA was thus expressed in terms of their individual proportion of correct answers on the test. However, "Shared SA" was defined as the minimum number of objects (transformed into a proportion) correctly reported or identified by a) all participants (n = 13), and b) all commanders (n = 4).

Level 2 SA was defined as translation of facts into an aggregated understanding of the current situation. Data was collected by assigning the participants a team task in which they were asked to describe the current activities and limitations of the different Bns (n=3) and also the main limitations affecting each Bn. The correctness of each description of each separate Bn was then judged by a rater from the High control, based on the system "ground truth". The rater used a two-step scale (0= Incorrect; 1= Correct), and the maximum possible score was 6. The scores were then transformed to proportion of correct answers which constituted the teams' level of level 2 SA. Shared level 2 SA was defined as the minimum number of correct descriptions given by all teams (n = 4).

Level 3 SA was defined as the parties' possible future actions and direction of movement, and also the estimated activities. Data was collected by assigning the participants a team task in which they were asked to describe what they thought would be the position of a set of predefined objects (n=10) six hours later. They were also asked to describe what they thought

would be the activities of the Bns and the Bde (n=4) six hours ahead. The solution presented by the Bns were compared with the one presented by the Bde staff in terms of similarity. Each object and description was judged to be either match or not match by a rater. One match generated one score. The scores of the Bn staffs were added together and transformed to proportion of correct answers which constituted the teams' level of Level 3 SA. Shared level 3 SA was defined as the number of correct descriptions, (i.e. similar to the Bde) given by all Bn teams (n = 3).

DV2: Response time to important events was defined as the time it took for the staffs to respond to important events injected to them in the scenario leading to the issuing of fragmentary orders (Frago). The measurement included both absolute time and perceived time efficiency of the staff process. The absolute time was measured from the moment where a "tagged inject" (an important scenario event) was presented in the scenario until a Frago was issued using the email system as a response to that inject. Also, after the set of runs which constituted a condition (HIM or NHIM), participants and observers where asked to judge and comment whether they thought that their staff had reacted to injects in a time efficient manner. This judgment was given on a six-step Likert-scale with the response options 1 = Totally Disagree, 2 = Mostly Disagree, 3 = Disagree more than I agree, 4 = Agree more than I disagree, 5 = Mostly agree, and 6 = Totally agree. Most of these judgments also required a free text explanation in order to support/explain the judgment.

DV3 Quality of orders and actions was defined as the quality of the Fragos being issued by the Bn Cdrs and the actions they took on the battlefield. After each condition, the Bn commander was asked to judge and comment (1) whether the Bns look out for the Bde's best interests, (2) whether the different Bns have had intents in alignment with the overall Bde intent; (3) whether the Bns had been competent in effecting necessary coordination and (4) able to plan and execute the mission with minimal supervision. In addition all participants and observers were asked to judge whether they were satisfied with the Frago produced and whether they thought it had been thoroughly worked out. These judgments were also given on the six-step Likert scale described under DV2 and complemented with free text comments.

DV4 Pattern of communication was defined as the direction and amount of communication in all available mediums between the different units. Communication in all mediums was logged through the system.

DV5: Time allocation of Bde Cdr was defined as the proportion of time allocated by the Bde Cdr to activities related to planning ahead for the Bde. A dedicated military observer followed the Bde Commander and was instructed to note down, in every 30-minute interval of the scenario runs, the activities the commander allocated his attention to. The noted activities were classified as either having a "current situation" or "planning ahead" focus. The judgment was made on a predefined proportion scale with 10% intervals (minimum 0 %, maximum 100% attention to planning ahead, in ten steps). The mean proportion of attention to planning ahead within each condition, rated by the observer, was used as one indicator of the Bde Commander's attention management. In addition, after each condition the Bde Cdr did a similar rating regarding his attention management for the scenario runs for each of the two conditions.

DV6: Subjective evaluation of NHIM and HIM was defined as the relative effectiveness of the two different procedures compared to each other in several different areas: (1) applicability in real-life operations, (2) reaction time to important battle-field events, (3) quality of orders produced, and (4) pattern of communication. Some of these judgments were also given on the six-step Likert scale as described under DV2, but some were given on a three-step scale with the response options e.g., 1 = slower in NHIM, 2 = No difference between NHIM and HIM, and 3 = Quicker in NHIM. In addition, the participants also stated

their general opinion regarding the feasibility of the two concepts, pros and cons, relative to each other. These measurements were taken after both conditions had been completed.

Confounding Variables

A set of variables, which if they occurred could affect the results of the experiment, were also defined and measured and they are briefly described in the following section.

System breakdowns: Participants and observers judged whether system failures that hindered the participants from acting their roles in the scenario had occurred.

Realism of scenario: Participants and observers judged (1) whether the scenario as such, (2) the amount of information provided, and (3) available time had been realistic enough in order for the participants to act their role in the scenario. They also rated the complexity of the scenario.

Team commitment: Participants and observers judged their perception of team spirit within their staff, the staff's commitment to the mission and to the performance of the Bde as a whole in order to make it possible to analyze whether their team commitment changed over time. The three confounding variables (System breakdown, realism of scenario and team commitment) were all measured on the same type of six-step Likert scale as described under DV2.

Completion of process: After each condition participants and observers judged whether the participants had executed the intended C2 process (i.e. NHIM or HIM) without deviations. This was judged on a Yes/No-scale with comments

Training effect: Participants and observers rated whether a training effect, making the participants more proficient in their roles, had occurred between the NHIM and the HIM conditions. This measurement was taken on the same type of three-step scale described under DV6.

Procedure

After 2+3 days of systems- and procedure training on both the HIM and NHIM procedure, as well as trying out the instruments for data collection the experiment started with two NHIM runs. After each run participants did the SA diagnosis (DV 1) and the military observers observing each staff reported data on dependent variables 2-5 through the observer protocols provided to them. After the second (and last) experimental NHIM run the participants filled in a questionnaire to evaluate the NHIM condition.

The first HIM run was a training run with no data collection and then commenced two experimental HIM runs following exactly the same data collection procedures as the NHIM runs with the addition of the questionnaire aimed at collecting data on DV6, the subjective comparison between the two conditions that was only taken after the final completion of both conditions. As the last activity for the participants, compiled and preliminary results were presented to them in order to get their feed-back on how the experiment team had evaluated the results.

Results

Confounding variables

Some *system failures* occurred during both runs. The perceived impact of these failures however was not severe. The mean value on the six-step Likert scale for the NHIM condition was = 2.85 (SD = .99) and for the HIM condition it was = 2.33 (SD = .78), indicating that the participants on average disagreed more than they agreed to the statement: "The technical systems hindered my work and thus affect the results of the experiment". Also, a paired

samples t-test showed no statistically significant difference ($t_{(12)} = 1.45$, p =.18) between the two conditions. Thus the conclusion was that system failures did not confound the results.

The four measures of *scenario realism* showed no statistically significant difference between the different condition) in the ANOVA (within subjects design) based on data from participants (n = 13, df = 9, $F = 1.83$, p = .21). On the six-step Likert scale the participants judged the complexity item and the three scenario realism items between 3.92 - 4,46 for NHIM (SD = .77 – 1.12) and between 3.77 – 4.54 for HIM (SD .66 – 1.00). The lowest value was the complexity rating. The participants and observers had some negative comments, but on average agreed on the statements that the scenario was realistic and complex. A few comments indicated that the scenario lacked some complexity regarding the civilian activities. The overall conclusion was that the limitations in scenario realism and complexity were small enough not to confound the results of the experiment and there was no difference in these respects between the two conditions.

On the three measures on *team commitment*, participants and observers mostly agreed on the statements that the team had high team spirit, contributing to accomplishing the whole mission, and was committed to the whole Bde's performance, and an ANOVA (within subjects design) showed no statistically significant difference in these respects between the two conditions (n = 13, df = 10, $F = 1.68$, p = .23). The observer ratings were in agreement with the participants judgments with no statistically significant differences (p > .50). On the six-step Likert scale participants and observers rated the three team commitment items between 5.24 – 5.29 for NHIM (SD = .44 – .59) and between 4.53 – 4.88 for HIM (SD 1.05 – 1.46). The overall conclusion was that the team commitment was high and did not differ between conditions and thus, should not confound the results of the experiment.

Regarding *completion of process* the observers and the participants did not report any deviances from the NHIM and HIM procedures during the runs, except for one participant who after the HIM condition reported that all reports of unit positions in the scenario was not reported hierarchically in his team. However, this must be considered a minor deviation of less importance for the overall results. Comments from the observers indicate that self-synchronization between Bns actually occurred during the NHIM runs. Also, in both conditions the participants agreed that they executed each of the two C2 processes effectively, ($M_{NHIM} = 4.53$, SD = .52; $M_{HIM} = 4.30$, SD = .85) and the paired samples t-test showed no statistically significant difference between the two conditions in this respect ($t_{(12)} = 1.15$, p = .27. In general participants commented that the process had improved over time. The conclusion was that the participants managed to execute both of the C2 processes according to the instructions and in a way they felt were effective, which means that the results are really based on testing of the two different conditions as intended.

Regarding *training effects* a small majority of the participants (54% or 7 participants) agreed that their staff had improved its ability to function from the NHIM to the HIM runs. Comments from these participants indicate that the improvement regarded a greater familiarity with the systems, the maps and the scenario and only one mentioned improved team competence as a reason for his judgment. The remaining 6 participants reported an equal ability for the team in both HIM and NHIM runs. The conclusion was that a training effect occurred in favor of the HIM condition, but it is very difficult to assess the implications on the result. One important conclusion though is that the training effect did not inflate the NHIM results unduly, but it is a risk that the positive effects of NHIM, where they occur, might be underestimated.

Dependent variables

DV1: Situation awareness

Our expectation was that the level of shared situation awareness should be higher in NHIM than in HIM. This was based on the fact that under the NHIM procedure more situational facts (such as map objects and reports) are directly visible on the sitmap in the collaborative C2 system (MM TOP), and also all participants were more exposed to communication between all other participants through the common voice/chat rooms, and they were expect to discuss more. In the HIM condition the situation information was also available but in some respects only for those who actively choose to search for it.

We analyzed the level of shared SA across the two conditions. Shared SA was defined as the number of correctly identified objects among all participants (for SA 1), or correctly made statements among all teams (for SA 2 and 3).

For shared SA 1 the number of objects in the situation picture correctly identified by all participants was 0 % in NHIM and very low (10%) in HIM, and because of that we decided to look at the agreement among commanders only. In Table 2 the *shared* SA results for all levels are indicated.

Table 2. *Results on shared SA expressed as proportion of correct responses for each run, divided in three different shared SA levels.*

	NHIM			HIM		
	Run 1 (%)	Run 2 (%)	M (SD)	Run 1 (%)	Run 2 (%)	M (SD)
SSA L1[a]	40	60	50 (14.1)	70	10	40 (42.4)
SSA L2[b]	67	50	58.3 (11.8)	83	67	75.0 (11.8)
SSA L3[c]	64	57	60.7 (5.1)	50	14	32.2 (25.2)

a = SSA L1 indicates the least number of situation map objects (transformed into a proportion) correctly identified by all four commanders.
b = SSA L2 indicates the least number of correct SA2 statements (transformed into a proportion) given by all four command teams (cdr + staff members).
c = SSA L3 indicates the least number of correct SA3 predictions (transformed into a proportion) given by all four command teams.

Based on mean values and standard deviations we calculated the effect size index, Cohen's *d* (Cohen, 1992), because it is less sensitive to small n. Cohen's d expresses the size of the effect as a proportion of the standard deviation. Thus a Cohen's *d* of 0.50 means that the effect of the experimental variable was half a standard deviation.

For shared SA1 the effect size was $d = 0.31$, which should be regarded as a week effect indicating an unsubstantial difference between the two conditions. For SSA 2 the effect size was 1.41, and an effect size stronger than 0.8 should be regarded as strong according to Cohen (1992). This means that shared SA2 (understanding of the current situation) was substantially better in HIM than in NHIM. For shared SA 3 the effect size was strong ($d = 1.57$), indicating a substantially better agreement among the teams regarding how to predict the development of the situation over time.

The main conclusion from the shared SA results was that the level of shared agreement among the different command teams regarding the current situation (SSA 2)was higher in HIM than in NHIM but the level of shared agreement regarding the predicted development of the situation over time (SSA 3) was higher in NHIM. This means that the expectation that the level of shared situation awareness should be higher in the NHIM condition was only partly supported by the results, but also partly disproved. However, the participants also made comments in their after experiment comparison between the two conditions (DV6), where six (of 13) mentioned increased SA/information sharing as a favorable effect of NHIM. The meaning of those comments was that a higher level of SA is accomplished *earlier* in the

NHIM condition, and that the Bns get a more holistic understanding of the battlefield. The way our SA measurements were designed for this experiment however made it impossible to capture the aspect of how early shared SA was obtained, because our measurements were taken at the end of each three-hour run.

DV2: Response time to important scenario events

Our expectation was that NHIM would result in faster and more responsive synchronization of blue actions on the battlefield. The rights/permission for the Bns to share information directly (timely), and coordinate directly with other Bns would thus result in shorter response time, that is, faster development and issue of Fragos to subordinated units in response to important events on the battlefield. All scenario runs included an injected event aimed at provoking a decision requiring a Frago.

For a scenario developer it is impossible to foresee exactly what response that will be elicited from the participants when they are confronted with a specific scenario event (inject), but the injects we used as triggers to Fragos in the scenario runs were designed to be of approximately the same complexity, at least between conditions, and they all required coordination between two or three Bns. They all regarded battle activities related to unforeseen enemy or armed hostile civilian activities, they were urgent, and they could be solved in less than three hours scenario time. Another problem was that all orders were not formally developed into a written Frago and issued through email by the participants. In several cases, the staffs developed and issued Fragos in a peace-meal way, using voice or chat communication. These Fragos were not possible to time.

However, during the two NHIM runs the Bde developed one written Frago, 443rd Bn developed two and 158th Bn developed one written Frago. During the two HIM runs the Bde developed two written Fragos, 443rd Bn one, and 158th Bn one Frago. The average time to develop those Fragos in the NHIM condition was 49.5 minutes (SD 18.2) and in the HIM condition it took on average 82.5 minutes (SD = 18.5). A t-test for dependent samples indicated that the difference was statistically significant ($t_{(2)} = 6.46$, $p < .05$). This result was also confirmed by the ratings done by the participants after the conduction of both conditions; 62% of the participants rated the reaction to incidents to be faster in the NHIM condition, 15% regarded the reaction time to be the same in both conditions, while the remaining 23% regarded the reaction time to be shorter in HIM.

Regarding the perceived time-efficiency of each staff as rated by the participants themselves, it was no difference between the conditions (M = 4.61 in both conditions). The participants mostly agreed to the statement: “My staff reacted to injects (incidents or important events) in a time efficient manner”. The interpretation of this result, also based on participants’ free text comments, was that given the circumstances in each different condition the staff members thought that they acted in a time-efficient manner. This was also verified by the military observers’ ratings.

The overall conclusion is thus that the NHIM condition resulted in shorter response times, or decision-loops, on the battlefield indicated by the fact that orders to subordinates regarding how to respond to unexpected (unplanned) events was issued considerably faster in the NHIM condition.

DV3: Quality of orders and actions

Regarding quality, our expectation was that the quality of orders and actions should be of about the same quality in NHIM as in HIM. After each condition the Bde Cdr had to disagree/agree on the six-step Likert scale to four different statements. The statements and the ratings after both the NHIM and HIM conditions were as follows:

(a) “The Bns looks out for the Bde’s best interests” (NHIM = 4 / HIM = 4);

(b) “The Bns’ intents are in alignment with the overall intent of the Bgd.” (5/5);

(c) “The Bns are competent in effecting the necessary co-ordination.” (4/3);

(d) “The Bns are able to plan and execute assigned missions competently with minimal supervision.” (4/3).

Item (c) and (d) were rated lower in HIM. The Bde Cdr’s written comments to those ratings after NHIM indicate that the low rating on item (c) was due to no Bn coordination taking place during the HIM condition, and on item (d) the reason was that the Bns were not allowed to plan and execute without supervision during the HIM condition. Thus the result indicates that the Bde Cdr regarded the quality of actions and orders to be satisfying in the NHIM condition and about the same level as in HIM.

Regarding the level of agreement to the two statements aimed at measuring the Frago quality after each condition the result was that the participants on average agreed to the two statements;

(a) “I am satisfied with the Fragos that my team produced today” (M_{NHIM} = 4.62, SD = .51; M_{HIM} = 4.08, SD = 1.44);

(b) “My team’s Fragos were thoroughly worked out” (M_{NHIM} = 4.65, SD = .65; M_{HIM} = 4.23, SD = .75).

There were no statistically significant differences between observers’ and participants judgments. The subsequent ANOVA (within subjects design) based on both participants and observers judgments on both items did not reveal any statistically significant differences between the two conditions (n = 17, df = 15, F = 2.01, p = .17).

Another measurement of Frago quality was taken after the completion of both conditions. In that measurement 54% of the participants reported that the quality of the Fragos was the same in both the NHIM and the HIM conditions, 23% perceived the quality to be higher in NHIM and 8% perceived it to be lower Frago quality in NHIM. The five comments provided as support for rating the Frago quality in NHIM as higher all refers to better information and/or coordination as a base for the Frago. The one reason provided for rating the quality as lower in NHIM was that no written Fragos were produced in that Bn during NHIM (42. Bn).

The overall result of all the Frago quality measurements indicate that self-coordination as in NHIM did not result in actions and orders of lower quality than when the coordination was done by the Bde, as in HIM, and thus supports our expectations regarding equal quality in the two conditions.

DV4: Pattern of communication

The expectation was that in NHIM the relative balance between communication Bn-Bn and Bde-Bn would be different compared to HIM. In NHIM we expected relatively more communication Bn-Bn (because of the need to take initiative to self-synchronize) and in the same time relatively less communication Bde-Bn than we did in HIM.

The patterns of various mediums of communication were obtained by processing the data log of all events involving the use of emails, voice communications and text chat. We were only interested in the communication activities that took place between the Bde with the Bns, and between the Bns. Communication activities that took place within the Bn, which involved discussions between the Bn HQ staff, and with the Bns’ subordinate commanders, were not included in the analysis as we regarded these to be independent of the two conditions. Therefore this measurement provided an overview of the volume of traffic for each of the communication mediums, namely Email, Voice and Text Chat, between the Bde and Bn HQs. The patterns of communication through different mediums for NHIM and HIM conditions are depicted on six diagrams in Appendix 1. The main differences between NHIM and HIM as can be read from the diagrams in Appendix 1 are the following:

a. The email traffic was low overall, while the voice communication traffic was high, indicating that the preference of the participants was to rely on voice communication rather than emails.
b. The email traffic pattern revealed that there were more Bn to Bn emails sent under the NHIM condition as compared to the HIM condition. Conversely, there were less Bde to Bn emails sent under the HIM condition.
c. The Bn to Bn voice traffic though the Command net and S3 net was also much higher in the NHIM condition compared to the HIM condition. The Bde to Bn voice traffic through the Comd net and S3 net was lower in the NHIM condition compared to HIM condition.
d. An interesting observation was made on the very low voice traffic contributed by all S2 officers to the S2 net, while the Command net and S3 net were comparably more active. This suggested that the S2s were largely handling internal communications to gather the situation picture while the Bn and Bde Commanders, together with the S3 officers were more involved in the coordination and self-synchronization activities between the units.

As a whole, the overall pattern of communication as indicated by the diagrams in Appendix 1 indicate more Bn to Bn communication and lesser Bde to Bn communication in the NHIM condition as compared to the HIM condition.

The participants also had to rate the relative amount of communication with other units as they perceived it. 69% of the participants agreed that it was more communication with other units in NHIM than in HIM; 23% regarded the amount to be the same in both conditions and 15% regarded it to be more communication in HIM. The free text comments provided by the participants indicated that more communication in NHIM was due to a greater need to coordinate activities between Bns directly (i.e. self-synchronization), and to discuss situation information. Those who regarded it to be more communication in the HIM condition mentioned as motives a greater need to communicate more about the Bde overall situation and other situation information as this type of information was less available in common overlays in the HIM condition. Taken together these ratings and comments provide support to the assumption that the NHIM condition should result in relatively more communication Bn – Bn and in the same time relatively less communication Bde – Bn than in the HIM condition.

If we look at the content of the communication as it was reported by the military observers a large part of the communication between the Bns in the NHIM run regarded self-synchronization both around tasks received from the Bde, involving more than one Bn (e.g. self-synchronization on capturing different parts of the same town) and around events encountered on the battlefield by one Bn, needing assistance or being offered assistance by another Bn (e.g. self-synchronization on how to take care of a large number of refugees).

DV5: Time Allocation of the Brigade Commander

The expectation was that in the NHIM condition the Bde should be less actively involved in coordination of current ops between the Bns and also in compiling reports and assessing the current situation. This should free time and mental resources that we expected to be used for planning ahead for later phases of the current operation. As we were not able to dedicate unique observers for each member of the Bde staff we decided to concentrate on how the Bde Cdr allocated his time in the two different conditions.

The observations by the dedicated Bde commander observer were divided into six 30 minute time periods per run. On average the Cdr focused 42.5 % of his attention during the NHIM condition on planning ahead (as opposed to attend to the current situation). However, the variation was relatively large over time (SD = 29.5). The corresponding value for the HIM

condition was 32.7% with a SD = 28.3, Thus a 10 % difference between the two conditions. However, a t-test for dependent samples showed no statistically significant differences between conditions ($p > .30$), although the difference was quite substantial.

After each condition the Bde Cdr also estimated on the same type of scale how much attention he had devoted to planning ahead during the two runs in each condition. His estimation was 60% during NHIM and 30% during HIM.

Both of these two measurements have obvious limitations. For the observer, he could only observe overt behaviors. He could not know what the Bde Cdr was doing all the time when he was not communicating or working with something in the C2 systems. If the Bde Cdr was sitting in silence, thinking, the observer would not know whether the Bde Cdr was planning ahead or not. For the Bde Cdr, he had to give a concluding judgment after two scenario runs, and this is of course difficult. The activities that were closer in time should be more available in his mind than more distant activities.

Statistically we cannot conclude that more of the Bde Cdr's attention was devoted to thinking ahead during the NHIM runs, but we still regard it as a clear trend in the data, and also what the Bde Cdr perceived. This interpretation is also supported by free text comments made by some participants as advantages with the NHIM condition. Comments were made with the meaning that the NHIM condition require less stress on the Bde staff on information sharing (1 comment), and that NHIM enables more forward planning (2 comments).

DV6: Subjective Evaluation of NHIM and HIM

As the participants of this study were professionals with insights on C2 we found it important to evaluate how they perceived the usability of the two different C2 models. Some of this evaluation has already been reported under other DVs, in the context where they belong, but the remaining evaluation comparing NHIM with HIM will be reported here.

Our expectation was that the NHIM procedure would be perceived as a better process than the HIM procedure and this was indicated by the results of the subjective evaluation. 77% of the participants agreed that they would prefer the NHIM procedure in a real-life field operation and the remaining 23% found NHIM and HIM to be equally good. No participant preferred HIM. On two related items participants, agreed more with NHIM ($M = 4.46$, $SD = 1.18$) as being an effective procedure in a real-life field operation compared to HIM ($M = 3.54$, $SD = 1.12$). A t-test for dependent samples indicated that this difference was statistically significant ($t_{(12)} = 2.31$, $p < .05$. In order to support their judgment the participants listed some advantages and disadvantages with NHIM and HIM.

The *advantages with NHIM* could be referred to three main areas (a) Self-synchronization is flexible and effective both during planning and execution (6 comments), (b) Information-sharing procedures (unrestricted) allows for faster and more total situation awareness (10 comments), and (c) Self-synchronization and information-sharing allows for better anticipation and planning ahead (5 comments). One sample comment covering area (a) and (c): "Flexible. Mostly speed up the C2 procedure. Does not need full control of a Bde commander and if the communication between subordinates and commander is disturbed, everything does not stop. Great chance to take advantage of upcoming situations on the battlefield."

The *disadvantages mentioned for NHIM* could be referred to the following four areas: (a) The HHQ risk to lose control, and situation awareness, over the events if subordinates are allowed to self-synchronize (3 comments), (b) unrestricted or total information-sharing can lead to information overload and it demands very clear SOP's in order to avoid problems (9 comments), (c) Time-limits and sensitive situations may call for HHQ coordination instead of self-synchronization (2 comments), and (d) Effective self-synchronization demands good personal knowledge and communications skills (1 comment). One sample comment covering area (b) and (d): "You need a good structure in the network, and well thought out SOP, in order not

to get chaos in the information system. You also need to know your co-workers to be able to communicate with them in an effective way, and that may take some time to do."

The *advantages mentioned for HIM* could be referred to the following four areas: (a) Better total awareness and control of information for the HHQ in HIM (3 comments), (b) the HIM procedure allows for quick decision making and control at the HHQ (4 comments), (c) HIM includes a more organized workflow with less risk for misunderstandings between subordinates (4 comments), and (d) HIM is an established C2 routine (1 comment). One sample comment covering area (b) and (c): "In some cases, the time for issuing orders and to make decisions is so short that you do not have the time to discuss and synchronize between subordinates. Then HIM is better. Also, when the commander needs to have full control over very complicated situations for some reason; also, to prevent misinterpretations between units. NHIM requires a complete information management structure to avoid information overload."

Finally, the *disadvantages mentioned for HIM* could be referred to the following four areas: (a) Higher workload at the HHQ level, both to gather information and make assessments and to coordinate between, and communicate with subordinates, this can take long time (8 comments), (b) Less total SA at the subordinated level (6 comments), and (c) It is more difficult for subordinates to take initiatives on the battlefield both because of lack of total awareness and a lack of rights to do so (2 comments). One sample comment covering area (a), (b) and (c): "Units are more hesitant to exercise initiative. They have less situation awareness. More voice communication needed."

The military observers also made notes regarding the relative effectiveness of NHIM and HIM. Some of these comments have the same general meaning as the ones' made by the participants, but some of these observer comments help to get a clearer picture and they are listed below. First, some comments to clarify the observers' opinions on the NHIM procedure:

- NHIM is efficient based on the following assumptions: 1. In actual battle situation, Bn has bandwidth and staffing to conduct battle and synchronisation. 2. Bn has the hardware support of both voice and data exchange for a richer conversation to allow meaningful self- synchronisation. 3. Certain level of team building and team member familiarity before the conduct of the mission is necessary. E.g. from one NHIM run: 158 Bn and 443 Bn collectively worked out a plan and proposed to the Bde for considerations.
- When the units grew accustomed to each other the commitment and the overall operation awareness seemed to increase.
- Examples from the NHIM runs in support of the NHIM procedure: *SITREPS from other units than 42 Bn where available to built up 42 Bn situation understanding. * Sharing overlays and MM collaboration tools made it easier to discuss problems. *Bde don't have to solve all coordination problems, thus "saving" time to use for other problems. * Bns can directly discuss upcoming situations and solve them without involving Bde, which gives a faster way of conducting operations.

Second, some comments to clarify the observers' opinions on the HIM procedure:

- HIM was design for a hierachical organisation, therefore it is naturally for HIM to be efficient in such a set up . Main difference (from the NHIM runs) is the relatively lack of situational awareness that required the Bde to spend more time to collate current picture before swinging into planning mode.
- HIM reduces flexibility and increases response time. Awareness about other units seem to be poorer and the confusion is greater compared to NHIM. More work has to be done at the higher co-ordinating level by people acting on second hand information.
- Examples from the HIM runs: *It was time consuming to handle information. * It takes time to send information "from one end to the other end". *The Bn displayed only own (Bn) forces on their sitmap, nothing about other Bns or boundaries. *The Bn staff is concentrating almost all attention on their own Bn situation.

Discussion

The main purpose of this study was to evaluate a new edge concept of sharing information, collaborate and coordinate battlefield activities, i.e. Non-Hierarchical Information Management (NHIM), complemented with rules for increased self-synchronization among the lower units. The concept was developed into a standing operating procedure (although not fully detailed) and thus was an attempt in line with current efforts to provide more "power to the edge" (Alberts & Hayes, 2003). The evaluation was conducted through a formal comparison between the new concept and a traditional hierarchical concept, i.e. Hierarchical Information Management, (HIM). The results indicated that the new concept was operationalized in an experiment environment as an efficient C2 *procedure*. This statement was supported by the fact that 10 out of 13 participants viewed NHIM as a more effective C2 process in real-life battlefield operations, and no one preferred HIM over NHIM. It was important to understand that the NHIM concept as operationalized for this study already included rules on how to self-synchronize between Bns. Observations, and the measurements of communication and attention management as well as comments from the participants themselves indicated that self-synchronization between Bns actually occurred, based on intent and tasks given from the Bde staff.

The main result of the study was that this Edge C2 procedure (i.e. NHIM) resulted in a faster decision-loop for the Bde/Bn system as manifested in the faster issuance of fragmentary orders. As mentioned in the introduction and in many other C2 literatures (e.g. Alberts & Hayes, 2003; Hanlon, 2004), the ability to respond quickly to threats and seizing opportunities on the battlefield is often seen as crucial for success. In essence, the speed of developing and issuance of new Fragos was one such testament of a quick response.

One reason for faster response was that much of the battlefield coordinations were carried out among the subordinated Bn commanders as indicated by higher volumes of communication between Bn to Bn in the NHIM condition. The obvious risk with the self-synchronization procedure was that such low-level coordination may not be in line with higher commander's intent. There was a possibility that faster response might risk having incorrect information and actions that may jeopardize overall mission effectiveness. However, the results from this study indicated that this was not the case. The quality of orders and actions taken by the Bn commanders in their self-synchronization was judged to be at least as effective as hierarchical Bde-coordinated orders and activities. This was consistently found to be true from the perspective of the Bde Cdr the Bns, and the military observers.

Another positive tendency in the NHIM procedure although not as clearly demonstrated was that it tended to free mental capacity among the members of the Bde. The results showed that the capacity was used for planning in the next bounds of operation. There were several reasons behind this effect. Firstly the Bde was less preoccupied with gathering, assessing and reporting situation information, because the Bns had already access to the same information as the Bde through the collaborative C2 system. Secondly, a substantial part of the coordinating activity for conducting current operations was already done by the Bns themselves.

However, our expectation that NHIM would result in a higher level of shared situation awareness was both supported and contradicted by the results and it is interesting to discuss why it was so. Regarding the higher shared awareness of the current situation (SSA2) in the HIM condition, the data did not suggest any obvious explanation and as such, we will refrain from making unsubstantiated guesswork. Regarding higher shared awareness regarding predicted development of the battlefield situation over time (SSA3), one simple explanation was that the obtained difference seems to be much dependent on a strong decrease in the SSA3 level in the last HIM run (see Table 3), which in turn could be explained by the fact that this was the last run in the experiment. As such, there was possibility of a lesser desire and interest to predict future scenario development in the minds of the participants. On the other

hand almost 50 % of the participants gave arguments in favor of NHIM. This had meant that the NHIM procedure did result in more information-sharing, which in turn resulted in a higher level of SA developed *earlier* as compared to HIM. The result that simultaneous collaboration between several entities in the C2 chain can lead to early development of shared SA was also found in an earlier study of integrated planning (Thunholm et. al., 2006). The more pervasive information-sharing in NHIM was also subjectively reported by some participants hence resulting in a more holistic understanding of the battlefield, i.e. a Bde perspective also among the Bns. Thus, it seems possible that the increased level of information-sharing in NHIM was the true reason behind the better level 3 SSA in the NHIM condition.

Validity issues

How valid are these results? Firstly, both the comments from the observers and participants indicated that the participants followed the two tested procedures as intended. This indicated that we had methodically tested what we had wanted to test. Secondly, except for a certain training effect acting in favor of HIM over NHIM, none of the confounding variables acted in favor of any condition, and our participants should at least be as experienced as a normal field unit although a bit less acquainted with working together as a team. There were however two limitations in the study that might affect the ability to generalize the results to a realistic field setting. One was the number of participants in each unit and the other factor was the complexity of the scenario. In the actual live environment the staff could have been supported by more staff officers as the operations at hand would be more complex than we had accomplished here under the experiment setting. However we concluded that we had found a rather good balance between the limited number of staff officers in each unit and the complexity of the scenario, and this opinion was supported by the perceptions of scenario realism, time-pressure and complexity reported by the participants. Our conclusion was therefore that the results should be fairly valid and if there was a tendency in the results it should be that the positive aspects of NHIM might be underestimated. Regarding the subjective evaluation of the two conditions given by the participants it seems possible that some so called *demand characteristics* could have influenced these data in favor of the NHIM condition. However, we thought that we had enough objective data evidence in this study to support our conclusions, and as the participants were rather experienced, they should not have been easily manipulated in favor of something they do not believe in.

Improvements to the NHIM procedure

As mentioned in the result section, it is important to realize that a successful implementation of the NHIM procedure into real field units require advancements or improvements in the technical C2 systems. There need to be enough computer capacity, connectivity, band-with, and a collaborative C2 application as well as communication channels' admitting voice and chat communication and email, and this is also a so far unsolved security constraint. However, if these issues were to be solved, we also identified a need to further clarify the NHIM procedure. The main problem is that all this information-sharing and common access to other units situation overlays and reports that is a part of NHIM demand a very clear information-management standing operating procedure. We need to clarify how many overlays should be used, how to name and store them, how to distribute rights to update them and how to store data in a common data base. We probably also need to develop effective search engines in order for different functional officers to search or even prescribe to information that is of interest to specific C2 functions. This work needs to be done before a second test of the NHIM concept is conducted.

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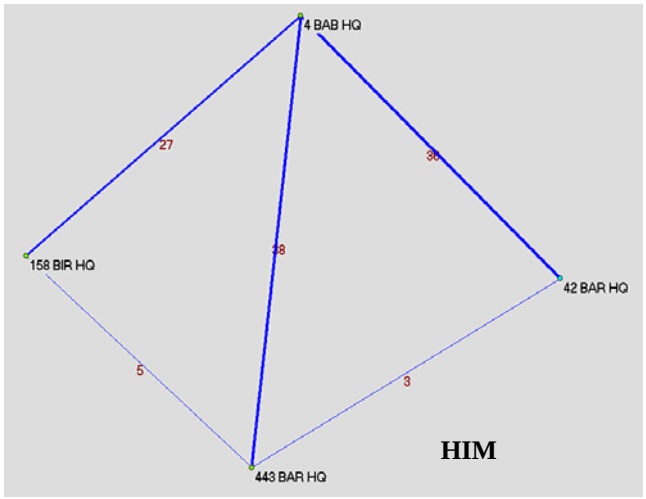
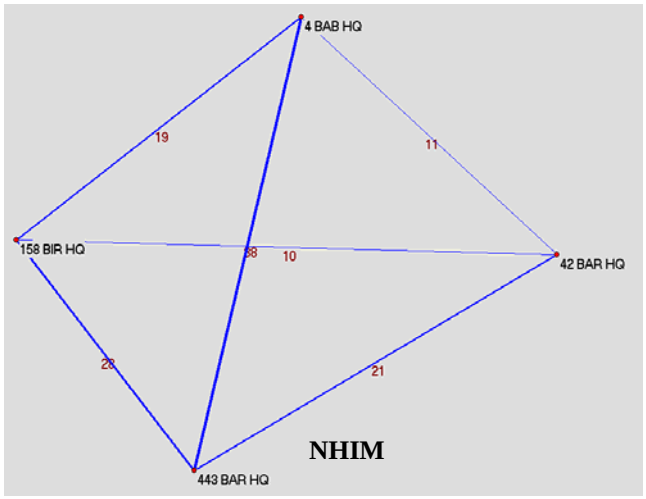
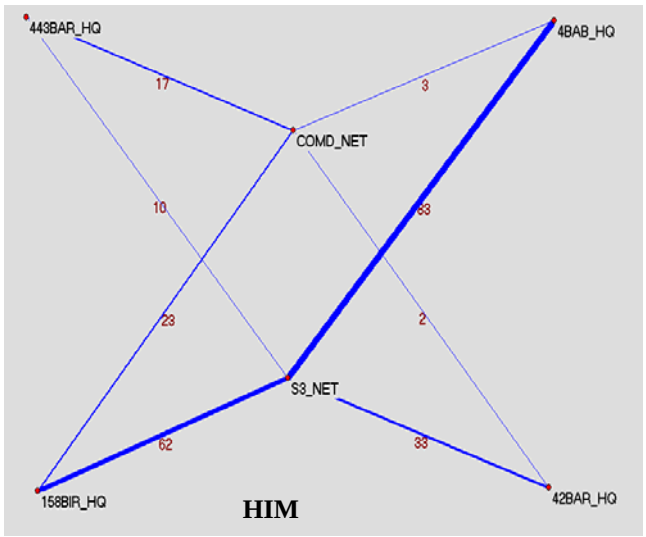
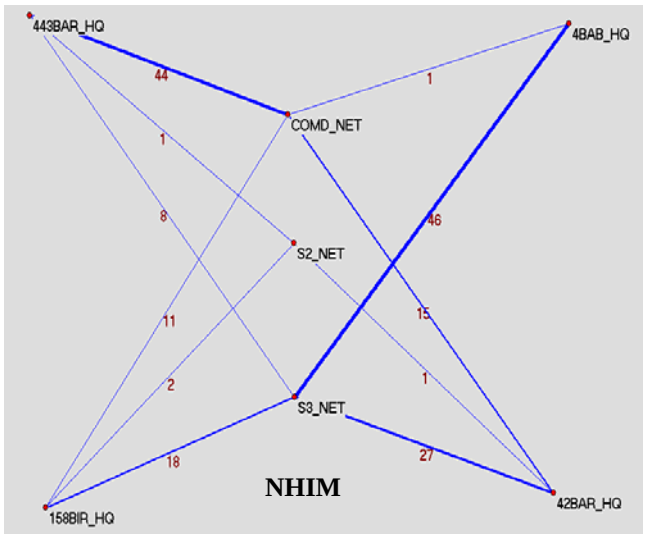
Appendix 1 - Communication diagrams for NHIM and HIM in three mediums



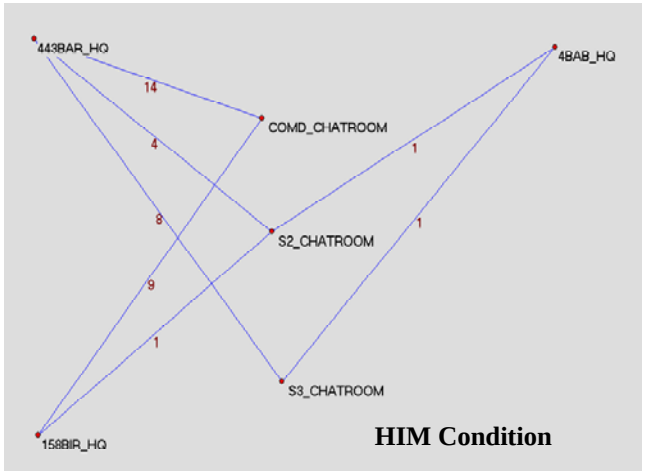


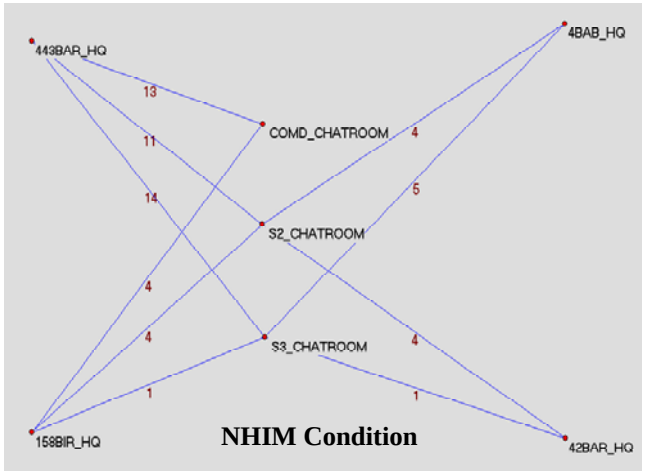
Email Traffic Patterns for HIM and NHIM runs





Voice Traffic Patterns for HIM and NHIM runs

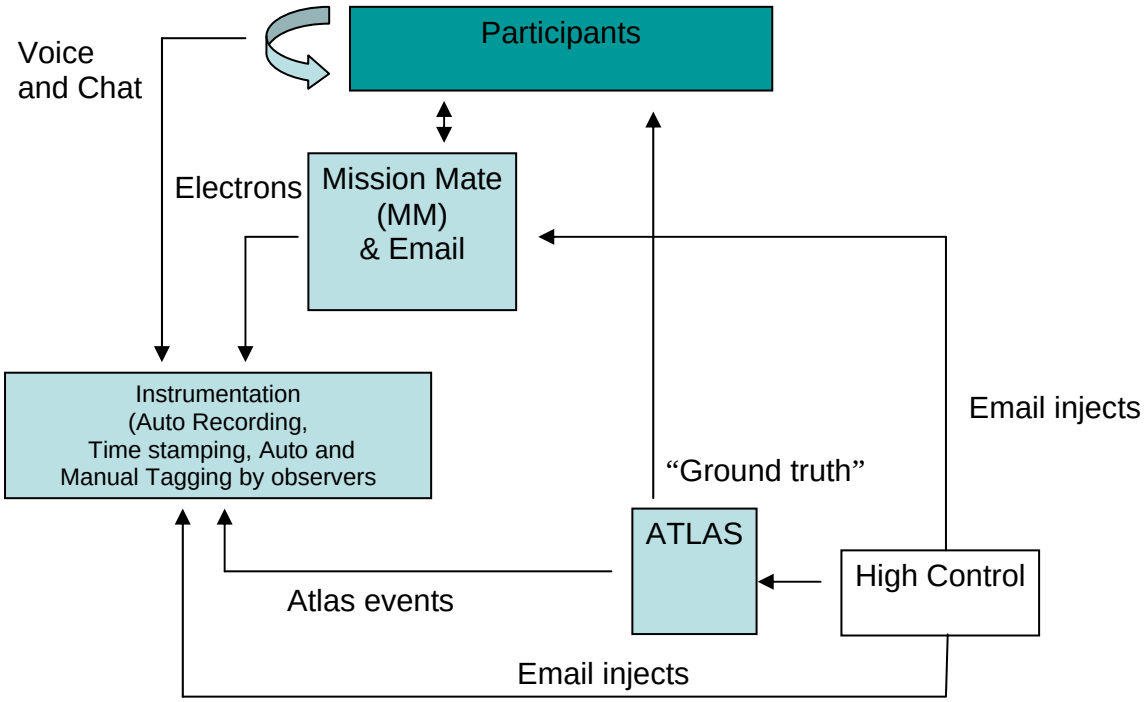




Text Chat Traffic Patterns for HIM and NHIM runs

Appendix 2 System Architecture and Experiment Layout

1. **Technical Architecture**. 5 technical systems were integrated and deployed in supporting FITX experiment. The Technical Architecture is illustrated below:



2. The 5 systems are:

1) ATLAS (Army Theatre Land Simulation System). ATLAS was deployed to provide necessary "ground truth" to ensure realism of the experiment. All units and activities in the scenario were simulated in the ATLAS wargaming system, which also determined the outcomes of all combat events between the opponents in the scenario. The ATLAS system is a time-step constructive simulation system designed to train Bde and Bn levels' Commanders and principal staff officers in decision making and operating procedures in the conduct of land operations employing land, air and naval assets. ATLAS was primarily designed to support Training Exercises in the SAF, and was customized for FITX for automatic generation and submission of Force location status and detection reports to Mission-Mate directly with little human in the loop.

2) MM (MissionMate). MM is a C2 system designed and developed by SCME to support experimentation. One of the key design features is it allowed rapid customization to suit new experiment conditions. Another key feature is that it supports map-based collaboration.

3) V300. V300 is another C2 system designed and developed by SCME to support and emulate tactical radio communications and text chat for the experiment participants. The system not only support real-time recording of voice and text communications among the participants but also screen-capture all the activities performed by the participants on MM and ATLAS. It addition, V300 also enable observers of the experiment to monitor and enter free text to note down events-of-

interest. Recorded and tagged data were archived and correlated to facilitate AAR (After Action Review) and selective search-retrieval-and-playback to support experiment data analysis.

4) Survey. This is an online survey system that handles participant profiling and SAGAT questionnaires.

5) Microsoft Outlook. It provides for text and media attachment exchange.

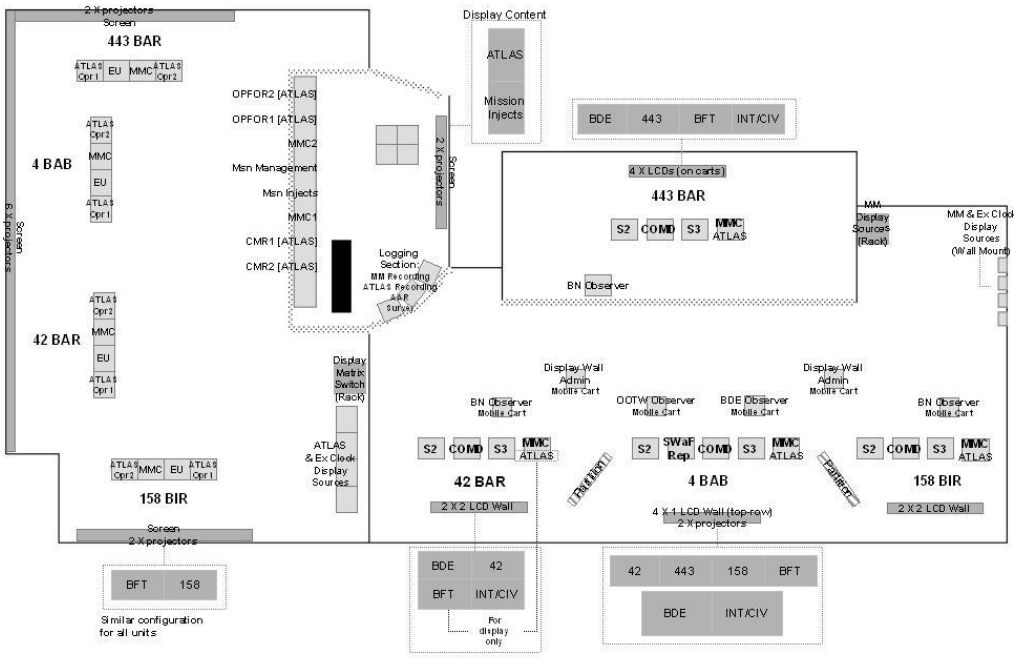
3. As this was the first time the 5 technical systems were integrated to support responsive plan-simulate cycles vis-à-vis NHIM/HIM modes-of-operation, extensive preparations was carried out to ensure overall system supportability:

a. Orientation and training program, technical and process drills were planned and structured to incrementally familiarize stakeholders and participants to system functions and process flow, and exposes them to experiment environment.

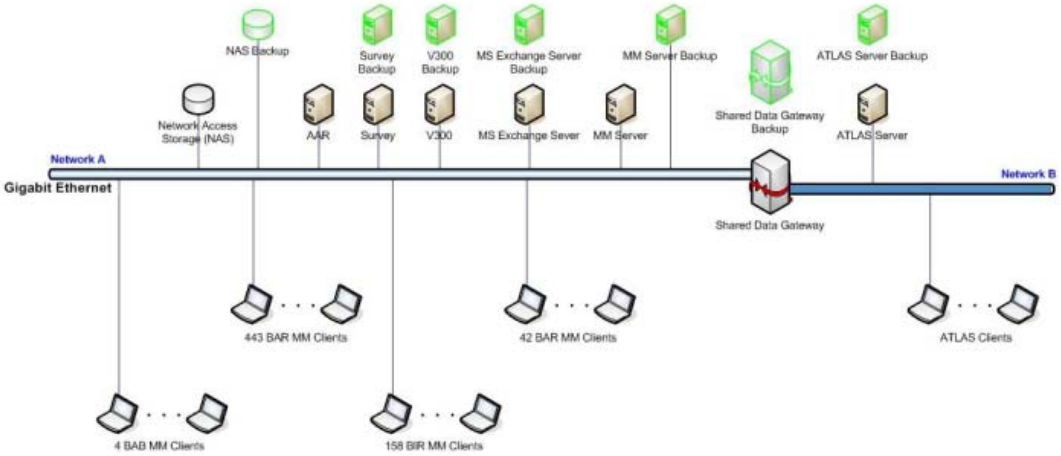
b. System Usage Protocols, Media Exchange Protocols and Naming Conventions were established and clearly defined to ensure experiment consistency, facilitate data collection, adhere to NHIM/HIM ground rules, and work-around system limitations.

c. High-Availability – Fail-Over measures were put in place to minimize downtime and recover data in the event of system failure with well-defined reporting structure to coordinate, update and initiate contingencies, if necessary.

4. **Layout.** The role-system layout is shown below:



5. **System Configuration.** The client-server setup and network topology are shown below:



6. **Scenario**

The scenario was set on the TEMASEK Island situated in the BISMARCK Sea. There were 3 States on the island: REDLAND, GOLDLAND and BLUELAND. All 3 States shared common borders with one another.

When the scenario play started, REDLAND had invaded GOLDLAND. BLUELAND, acting in response to a UN mandate, had begun operations on the ground in order to force REDLAND to withdraw its forces from GOLDLAND and to preserve the border between REDLAND and GOLDLAND. BLUELAND was attacking with a mechanized division along two main axes. The participants role played one of the two mechanized Bdes belonging to the division. REDLAND was defending from positions in GOLDLAND and there were also refugees from GOLDLAND and other CMR incidents going on that had to be dealt with by the BLUELAND forces.