16th ICCRTS

"Collective C2 in Multinational Civil-Military Operations"

Exploring Effects of C2 Warfare on C2 Ability in a Simulated Environment

Topic 6: Experimentation, Metrics and Analysis

Magdalena Granåsen, Patrik Lif, Per-Anders Oskarsson,
Peter Klum, Lars Tydén, Niklas Hallberg

Swedish Defence Research Agency, FOI
Department of Information Systems
SE 58111 Linköping, Sweden
Ph: +46 13 37 80 00

Point of Contact
Magdalena Granåsen
magdalena.granasen@foi.se

Abstract

Information Operations (InfoOps) can be used by or affect all kinds of actors in a multinational, civil-military operation. To explore issues related to command and control (C2) and information operations, a simulation environment was developed in which a series of experiments was performed. The simulator is called the Command and Control Warfare Demonstrator (C2WD). In the C2WD, C2 warfare in terms of electronic warfare (EW) and computer network operations (CNO) can be used to facilitate or reduce certain aspects of a staff's C2 ability. During experiments, military InfoOps experts formed a team responsible for C2W resources in a fictive peace keeping mission. The scenario was developed as being comprehensive, involving both civil and military aspects. Data collection was based on a hypothesis of ten prerequisites for C2 and included performance measures, self estimations, observations, system logs, video and screen recordings. A synchronized replay of all data sources was performed in order to compare the results from the different sources. The main findings are that the ten prerequisites for C2 seem to explain C2 ability. Based on these findings, a LISREL model was developed, where four factors with causal connections were created, visualizing the relations between these prerequisites.

Introduction

Military Command and Control may be defined as "the Organisation, Process, Procedures and Systems necessary to allow timely political and military decision making and to enable military commanders to direct and control military forces" (NATO, 2004). The ability to make these decisions are dependent on a number of factors such as access to correct and relevant information, understanding of the mission intent understanding of the situation in which the mission takes place and an adequate information flow between subordinates and superiors. This paper aims to describe the methodology and results of studying C2 ability within the setting of a C2 Warfare Demonstrator (C2WD).

During the development process of the C2WD, technology was developed simultaneously with methods for assessing command and control ability. A hypothesis of prerequisites for C2 was developed, based on current research as well as doctrines and expertise knowledge regarding command and control processes in the Armed Forces (Hammervik et. al, 2007; Hammervik et. al, 2009). Earlier experiments in the demonstrator environment resulted in revision of the original hypothesis in that new prerequisites were added and reformulated, but it has never been found that any of the prerequisites would be redundant or unnecessary. The current experiments are based on the revised hypothesis, which contained ten prerequisites (Figure 1).

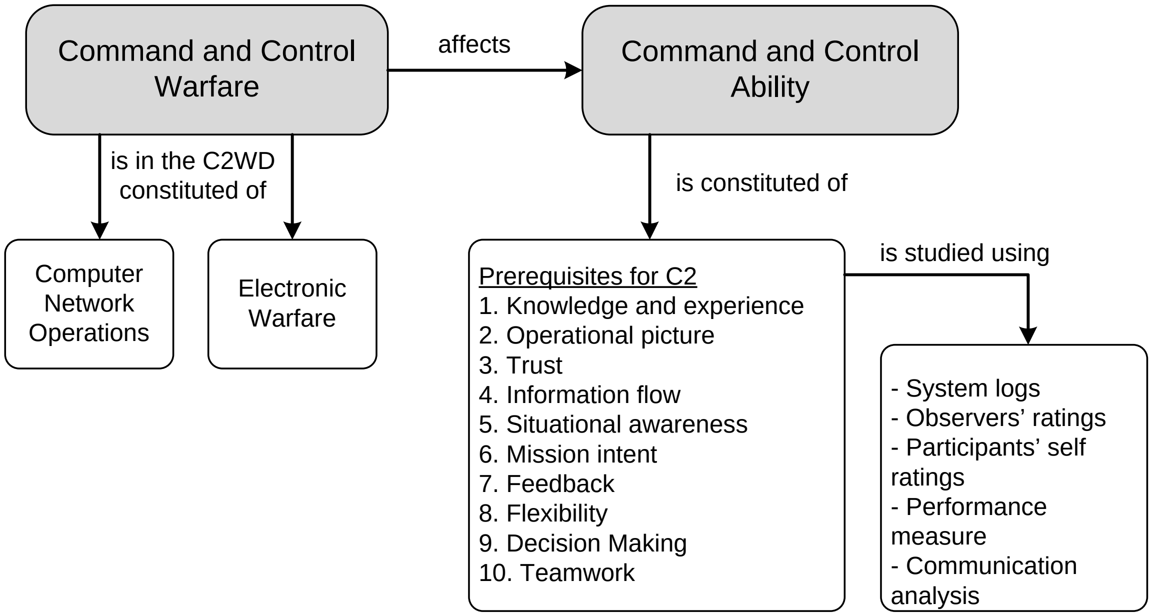

Figure 1. Hypothesis of the 10 prerequisites for Command and Control Ability. C2 warfare (in terms of CNO and EW) may affect C2 ability, which is constituted of 10 prerequisites. In the demonstrator environment, this is studied qualitatively and quantitatively, using both objective and subjective measures.

There is support in research and literature for that the terms that are called prerequisites are central aspects constituting C2 ability. Decision making is a huge research area in which Klein (Klein et. al, 1993) and Rasmussen (Rasmussen, Brehmer & Leplat, 1991) are two central contributors. The area of situational awareness is complex, yet well recognized term within human factors (Endsley, Bolte & Jones, 2003), which has been studied in different areas such as military systems (Matthews et. al, 2000) teamwork (Bolstad & Endsley, 2000), decision making (Endsley, 2004) and electronic warfare (Riley, Kaber & Draper, 2004). Feedback is shown to affect performance both positively and negatively, depending on type of feedback given as well as delays in the feedback (Lim, O'Connor & Remus, 2005; Atkins, Wood & Rutgers, 2002; Brehmer, 1989, 1992). Collaboration and teamwork is another central area (Janis, Cannon-Bowers & Salas, 1998; Beaubien, Baker & Holtzman, 2003; Brannick, Salas & Prince, 1998) which also has been studied nationally in a Swedish military context (Höglund, Berggren & Nählinder, 2009; Svensson & Andersson, 2006; Cheah et. al, 2005). Also trust has been identified both nationally and internationally as a central aspect in command and control (Andersson, Malm & Thuren, 2003; Lee & See, 2004).

The Swedish Defence Research Agency was tasked by the Swedish Armed Forces to develop a Command and Control Warfare Demonstrator with the purpose of being a platform for studying C2 ability in a C2 warfare setting, where C2 warfare mainly focused on electronic warfare (EW) and computer network operations (CNO). In the demonstrator environment, C2 warfare can be used to impair the C2 ability of an opponent or to improve one's own C2 ability (Tyden, et. al, 2009). This can be done by a number of means including to disturb the opponent's lines of communication, plant false information into the opponent's information systems and explore information about the intentions or capabilities of an opponent. The demonstrator has been developed using an evolutionary approach where experiments were used for validation of the current version of the technical platform as well as collecting requirements for further development of technology, scenarios and methods for assessing command and control ability. Methodological issues related to the C2WD have addressed the key question of how the effects of C2 warfare on C2 ability can be assessed.

This paper describes two experiments in which C2 ability has been studied within a demonstrator setting, and also reports results of the analysis of C2 ability. During the experiments, a simulated environment in form of the C2WD was used, focusing on Electronic Warfare (EW) and Computer Network Operations (CNO) for exploitation, countermeasures or counter-countermeasures.

Method

Participants

Two similar experiments were conducted. In each experiment a military staff was formed, consisting of three persons in the first experiment and four persons in the second experiment. All staff members were employed by the Swedish Armed Forces and working with information operation related issues (EW, CNO, psychological operations, PSYOPS). Five were military officers and two were civilian employees. The composed staffs were estimated as comparable in terms of competence and familiarity, in that participants in each staff were familiar with each other.

Procedure

Each staff received a full day of briefings and training in the demonstrator environment one day before their respective experiment started. Each experiment (simulation) lasted for two days with break during the night. During the experiments, two assistants from the C2WD development team were responsible for making inputs into the technical platform, management of web pages and e-mail, on orders from the staff. Operational picture, web pages and e-mail interface were projected in front of the staff. A higher chief in command (HIC) orally communicated the mission order and situation briefing before the simulation started. During the simulation, the staff and HIC communicated via e-mail. The staff reported their activities and asked questions to HIC, and they received orders and information from the HIC. A game control team simulated the opposing forces and coordinating units in the scenario. HIC coordinated all injects towards the staff. Staff members, staff assistants, game control team, HIC and observers were all located in the same room during the experiment (Figure 2).

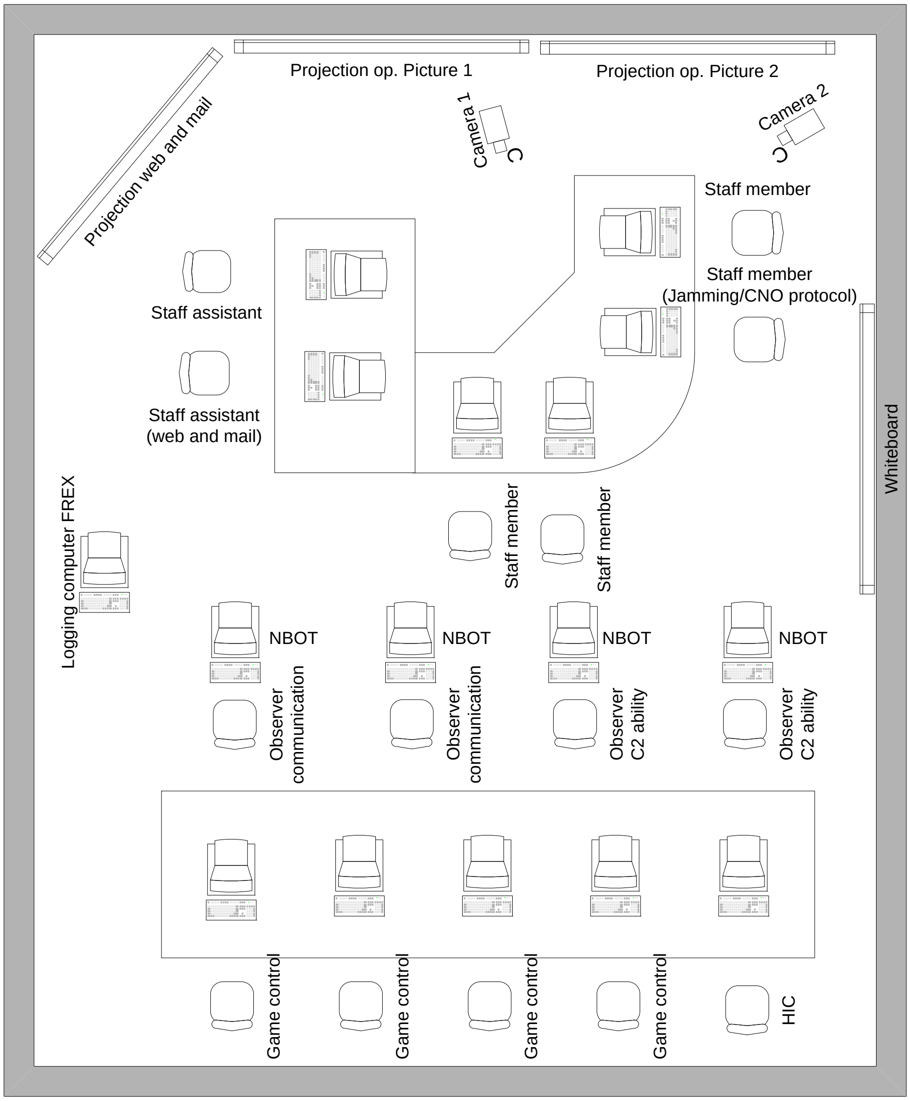

Figure 2. Arrangement of personnel and equipment during the experiments.

Scenario and simulated environment

The scenario took place in a fictive country in which an international task force recently had deployed. The participants played staff of a subunit of the taskforce, responsible for the EW and CNO resources, such as units with the capability of performing signal intelligence, scanning computer networks, and active means such as radio and radar jamming. The task was to support the evacuation of three NGO:s (non-governmental organizations) and key government personnel. The scenario included two phases, the intelligence phase and the evacuation phase. The task for the first simulation day (i.e. intelligence phase) was to map activities in the operational area that could pose a threat to the task force or the evacuation of NGO/government personnel. Based on the information obtained during the intelligence phase, the staff recommended evacuation routes and suggested necessary actions to ensure the evacuations. The task for the second day (i.e. evacuation phase) was to monitor the evacuation, report threats and perform necessary activities in order to secure the evacuation (e.g. jamming). Threats towards the task force included both conventional military units and criminal, irregular actors, which also possessed EW- and CNO resources. Mapping of these criminal actors, their resources and their social network were essential tasks for the staff. The staff obtained information mainly by using signal intelligence (i.e. radio, radar, and mobile telephone communication), monitoring social media and web pages, and intelligence reports from HIC.

The version of the C2WD used in the experiment included a wide range of functionality to perform simulation in a C2 Warfare setting. Particularly, the EW models were advanced, which meant that many real world physical effects could be simulated. During the experiments, the staffs were able to acquire information using active and passive sensors such as IRST, radar and radio intelligence, perform electronic counter measures (against radar, radio and mobile telephones) and use different kinds of CNO functionality, including passive and active network scan, DOS (Denial of Service) attacks and planting spyware. The different actors in the scenario were pre-defined in terms of platforms for air, land and sea equipped with sensors, countermeasures and communication equipment with certain ranges. The three-dimensional terrain model affected sensor performance and radio range in a realistic way. The staff also used the demonstrator environment for electronically sending and receiving messages (orders, reports) and monitor fictive web pages that were part of the scenario. The demonstrator environment allowed information to be shown on different types of views that were projected simultaneously on different screens. Own and detected units were shown on a geographical map, but there were also logical network and communication views used for instance for the social network analysis, as well as web and e-mail interfaces.

Visualising the effects of CNO and EW was critical, since the staff needed to be able to detect exposure to hostile measures in order to be able to calculate risks and take effects in order to solve the task of evacuation of the NGO/government personnel. Radio communication jamming could be detected by the staff in that they were unable to communicate with units in a certain frequency spectrum. Certain units were equipped with a Blue Force Tracking system, which meant that they automatically sent reports of their position. If a subordinate unit that was supposed to be under transport suddenly seemed to stop in the operational picture, it could be a sign of jamming connected to GPS. Radar jamming was simulated as DRFM (digital radio frequent memory), which meant that several false target appeared in the operational picture. For detection of intrusion in computer systems, the staff could activate IDS (intrusion detection systems). However, especially for CNO, attacks are not always easily detected. For those cases, secondary effects were used, so that the staff would be able to note that they had been attacked. Such effects included that internal system information about the international force was published on the irregulars' home page, e-mails with strange text (although with a trusted sender) appeared in the mail box or information on a public news web page was replaced by information promoting the irregular force. The staff also received intelligence reports to guide them towards a certain threat or area. In sum, to be able to detect exposure to attacks, the staff needed not only to activate automatic warning system but also actively scan their systems and the operational picture for indications, question the information seen and use information from several sources. A subordinate unit not responding to radio calls could be a sign of jamming, but it could also be deployed out of range.

Data collection

Data collection consisted of both subjective and objective data in form of observations, staff members' self estimations and questionnaires before, during and after the experiment, measurement of performance using an objective performance measure, system logs, video and audio recordings, and recordings of all screens used by the staff, HIC and game control. During experiments, two observers were responsible for command and control aspects and two observers were responsible for observing the communication. Observers used pre-defined schemes created in the observation software NBOT (Network-Based Observation Tool), developed by the Swedish Defence Research Agency (Thorstensson, 2008).

An individual background survey was completed by the staff members in order to obtain information about their knowledge and experience within EW, CNO and staff work. A survey was also completed by the staff members after each day, containing questions related to the prerequisites for C2 and evaluation of the experiment. Three to four times each simulation day, observers and staff members completed a survey of the prerequisites for C2, estimating to which extent the prerequisites for C2 were fulfilled on a scale from one to seven. During the first experiment, the survey of prerequisites was completed seven times and during the second eight times. Although there were ten prerequisites for C2, the survey contained 13 items, since the prerequisite Trust was divided into trust for staff assistant, other staff members and technology used. Furthermore, C2 as a whole was rated.

During the simulation, one of the staff members was also responsible for reporting experienced CNO, radar jamming and communication jamming towards the force. This survey was taken every four minutes. Estimations were graded as 1) No jamming/CNO, 2) jamming/CNO with minor impact on staff's C2 ability, and 3) jamming/CNO with major impact on staff's C2 ability.

An objective performance measure was developed based on the simulation manuscript (describing all events and injects towards the staff), assigning scores based on how the staff reacted to the events. The staff assigned scores for detecting, identifying and reporting events. Scoring was conducted afterwards using system logs, e-mail logs and synchronized replays of the simulation. For replaying the simulations and the chain of events that had occurred during the exercise, an in-house developed multi-media tool and methods for synchronized reconstruction called F-REX was used (Andersson 2009; Pilemalm, Andersson & Hallberg, 2008). This approach allowed subject matter experts to trace back and analyze events of interest that had happened earlier during the simulation runs.

Results

In this study, emphasis lies on the prerequisites for C2. Factor analysis, multidimensional scaling (MDS) (Davison & Sireci, 2000; Young, 1985) and LISREL (Jöreskog & Sörbom, 1993; Diamantopoulus & Siguaw, 2000) analyses of participants' and observers' ratings of these prerequisites were performed in order to identify how the prerequisites clustered and to analyze relations between the different prerequisites. In parallel to this, the experiment results included for example performance assessment using an objective performance measure, qualitative analysis of situational awareness and reliability analysis. The qualitative situational awareness analysis and the performance analysis are presented briefly in this paper since they are of interest in the methodological discussion and provide a context to the C2 ratings.

As described in the methods section, the survey with the prerequisites for C2 was completed by participants and observers during three to four times each day and included 13 items (one for each prerequisite, however trust was three-fold and a total value for C2 ability was rated). A multiple analysis of regression was performed based on these ratings, in order to analyze to what extent the ten prerequisites for C2 explained the rating of C2 ability as a whole. The prerequisites (12 items) were used as predictors and the total C2 ability rating was used as criteria. The analysis resulted in the multiple correlation coefficient of $R = .83$, $p < 0.01$, $R^2 = .70$. That is, the prerequisites explained 70% of the variance of the rating of C2 ability as a whole. It was found that Operational picture (40%), Trust for technology (37%), Situational Awareness (42%) and Decision Making (31%) had the largest amount of common variance with the C2 ability as a whole. However, all correlations were significant, that is, based on this analysis, all prerequisites seem relevant for how the observers and staff members rate C2 ability as a whole. The MDS analysis showed the graphical representation of the ratings of single prerequisites and C2 ability as a whole (Figure 3). The shape of this graphical representation, in which C2 ability is placed in the centre and all other prerequisites are placed around this item, has been obtained in earlier experiments with the demonstrator (Hammervik, 2007). As seen in the Figure 3, the prerequisites are all separate, that is, from this analysis no prerequisites can be interpreted as identical items. Factor analysis was used to identify the clusters which are circled in Figure 3.

The factor analysis (extraction with Principal Axis Factoring, Oblimin rotation with Kaiser Normalization) included all prerequisites, but not the total value of C2 ability (KMO = .84; Bartlett's test of sphericity, $\chi^2 = 696.16$, df = 66, $p < .001$). It resulted in three factors similar to Figure 3. The Mission intent prerequisite, however, was included in the factor with the prerequisites Trust A (trust for staff assistant), Trust C (trust for other staff members) and Teamwork. Since Mission intent had the lowest value in this factor, a separate factor analysis was conducted on this factor (KMO = .75; Bartlett's test of sphericity, $\chi^2 = 248.81$, df = 6, $p < .001$). According to this analysis, Mission intent could be considered as a separate factor, which is illustrated by the circles in Figure 3.

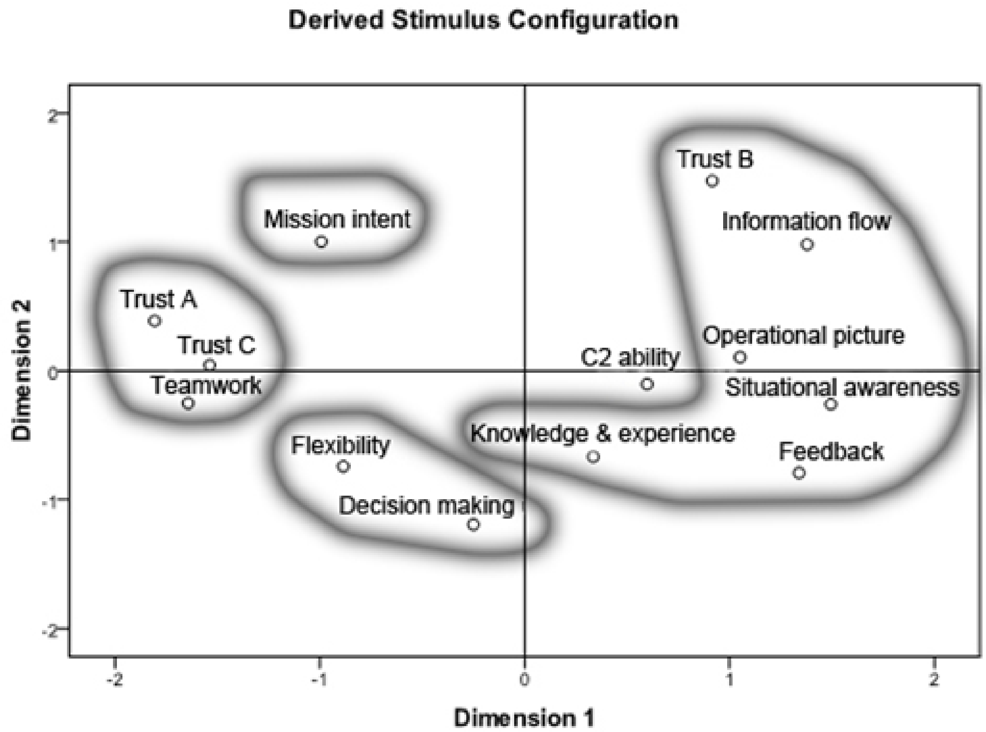

Figure 3. MDS analysis of the prerequisites for C2 (Trust A= Staff assistant, Trust B = technology, Trust C = staff members). According to the factor analysis on which the LISREL is based, the circled terms are related.

Reliability analysis of the clusters in Figure 3 showed high reliability of the situation factor, $\alpha = .82$ (Chronbach's alpha), and the team factor, $\alpha = .86$, and acceptable reliability of the decision factor, $\alpha = .72$ (for factor naming see Figure 4)

The pattern of the MDS analysis was confirmed and further explored in a causal analysis with linear structural equation modelling using the LISREL software (Jöreskog & Sörbom, 1993). The LISREL model produced is shown in Figure 4. During analysis, four latent variables were created (in Figure 4 shown as ovals), explaining the variance between the manifest variables (shown as squares in the figure). RMSEA (Root Mean Square Error of Approximation) = 0.063; CFI (Comparative Fit-Index) = 0.96, showing a good fit of the model.

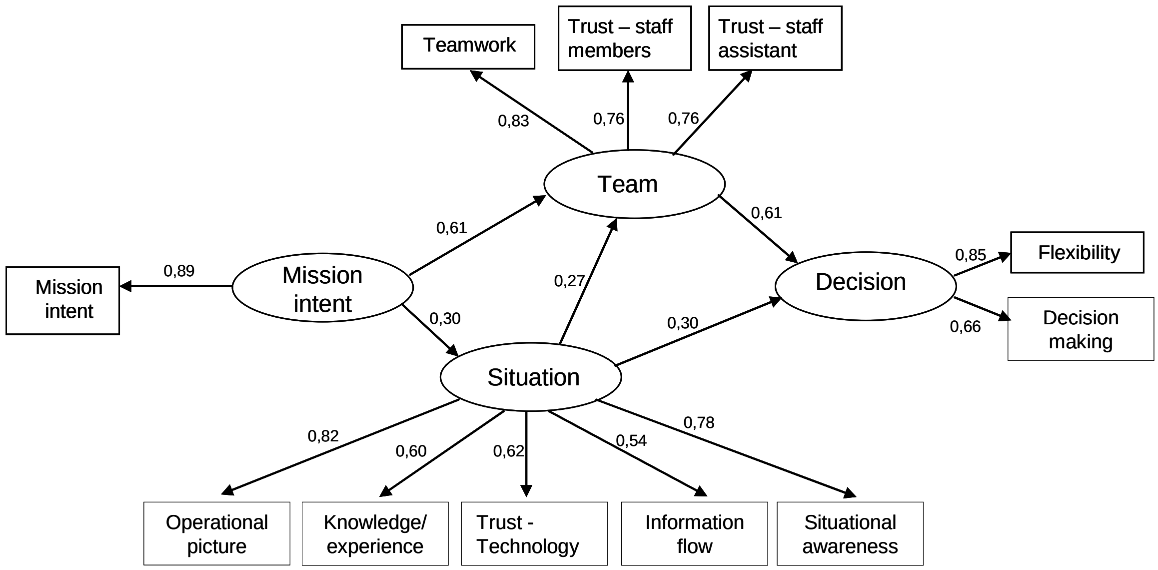

Figure 4. LISREL model describing the relations between the eleven manifest variables (squares), the four latent variables (ovals) and the factor loads.

As shown in the LISREL model in Figure 4, Mission intent affects both the Team factor (.61) and the situation factor (.30), with larger impact on the Team factor. The Situation factor affects both the team factor (.27) and the Decision factor (.30). The Team factor has larger impact on the Decision factor (.61) than the Situation factor has (.30). That is, the most important path in the model is Mission intent → Team → Decision.

The latent variables are principally the same as the clusters/factors in the MDS and the factor analyses, except for Feedback which was excluded in the LISREL model, since it had significant loadings on the three latent variables - team, situation and decision.

Situation awareness was qualitatively analysed in that comparisons were made between system logs and the participants' estimations of when they were exposed to electronic attacks (radio or radar jamming) or computer network operations. Results of the actual EW attacks and CNO were found in the system logs, while the results of whether the staff considered themselves exposed to such activities were generated from the NBOT tool in which these data were reported by the staff with 4-minutes interval or as soon as they discovered that they were exposed to CNO or EW attack. Exposure to CNO or EW could be detected in different ways by the staff, such as warnings by IDS, reports or lack of reports from subordinate units, signs of information leakage or information distortion. For each experiment and phase, a graph was produced, showing experienced and actual exposure to hostile EW and CNO. An example from the second phase of the first experiment is shown in Figure 5. Interesting events could then be noted, for instance when staff had noted jamming although logs showed that there was no jamming, and when they did not recognize that they were exposed to an attack. These situations were analyzed using the F-REX tool. These specific events are marked with a red circle in Figure 5 and explained in Table 1. Analysis of actual and experienced jamming/CNO show that SA was quite high among participants, since most actual jamming and CNO was detected by the participants. However, from the graph it seems as the staff, although that they detected that they were exposed to an attack, they did not immediately realise which type of attack, and therefore they noted that they were exposed to both communication jamming and CNO. Replay of the communication within the staff revealed that after a while, they usually detected the correct type of attack. Thus, the graph may be used as a tool to be able to give a first general overview on the staff's situational awareness, but for a detailed and fair analysis, it is necessary to replay data sources for the critical events identified. That is what has been done in order to generate table 1.

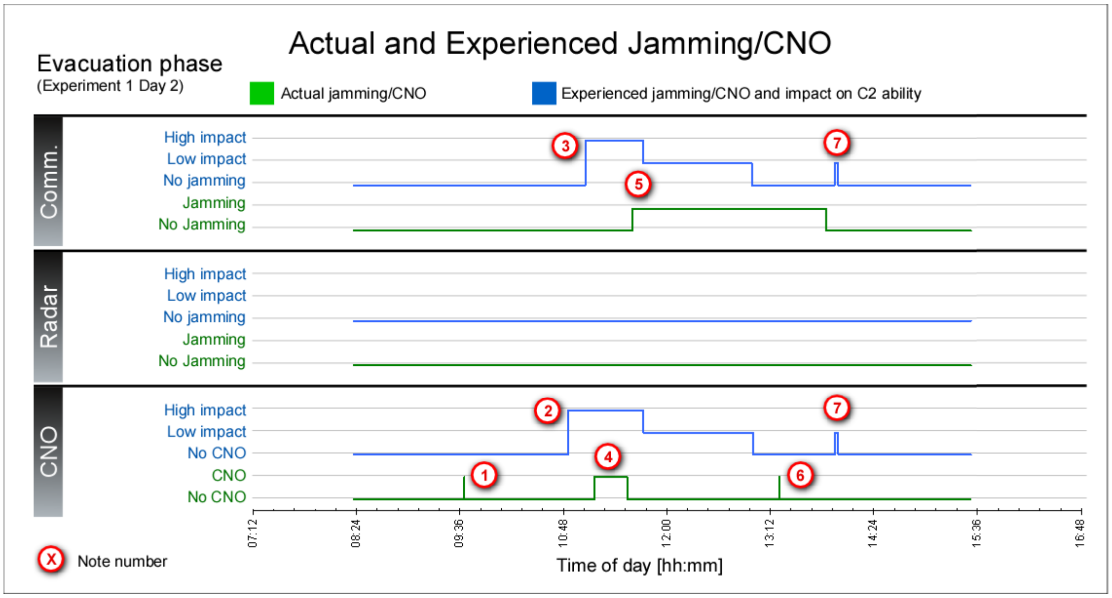

Figure 5. Example of actual and experienced exposure to communication jamming, radar jamming and CNO (experiment 1, evacuation phase) against the staff. When the staff experienced exposure, they also rated whether it had a high or low impact on their C2 ability.

Table 1. F-REX analysis of specific events found during comparison of actual and experienced exposure to EW and CNO (experiment 1, evacuation phase).

Note	Time	Comment
1	09:38	Intrusion in mail server. Discovered by the staff at 10:51, see note 2.
2	10:51	Staff discovers that information about IP addresses and mail conversation within the force is published on Internet.
3	11:03	Staff interprets the information leakage in note 2 as communication jamming.
4	11:08	The staff receives an e-mail with HIC as sender, however this is a false e-mail, which the staff immediately detects. Staff informs HIC by using an alternative line of communication (radio).
5	11:35	Communication jamming of GPS, staff detects that positions of own units are not updated.
6	13:18	The daily newspaper www.aftonblaskan.sl is hacked according to the log. However, F-REX analysis shows that this intrusion is not indicated in the interfaces in a way that the staff can see it.
7	13:56	The note on CNO is probably a false note by the staff member, F-REX analyses show that hostile CNO is not indicated in simulated systems, and staff does not discuss being attacked at the current event.

Performance was assessed for both phases of each experiment using the objective performance measure. Results show that the staff in Experiment 1 performed 60% of maximum score (60% day 1, 61% day 2) and staff in Experiment 2 performed 69% (69% day 1, 70% day 2). One reason to differences in performance may be that the staff members in experiment 2 were more familiar working with each other. Differences in knowledge and experience is a possible explanation, however not plausible since the differences in knowledge and experience rather pointed to that staff members in Experiment 1 had advantages in terms of competence and experience. Qualitatively, the performance is assessed to be good, since both staffs managed to solve most of the issues appearing during the simulation.

Discussion

From MDS and LISREL analyses it can be concluded that the prerequisites seem to group into two main factors – the Situation and the Team factor. The Mission intent affects both of these factors and these in turn affect the Decision. The prerequisites that form the team factor seem to affect the decision more than prerequisites related to the Situation factor. The feedback prerequisite needs more investigation, it is not clear whether it should be reformulated, removed or incorporated in another prerequisite. Both participants and observers thought that this prerequisite was particularly difficult to estimate, and perhaps it was not described to them in a clear way. These results are based on observers' and participants' ratings during the experiment, that is, the actual quality of the decisions was not known but it was rather the flexibility and the timeliness of decisions that were assessed. Since these results are based on ratings, the next step would be to analyze prerequisites from objective measures. However one must note that participants' ratings of some of the prerequisites may be more reliable than observers' or other types of "objective" measures (such as trust and knowledge), and some prerequisites may not be interesting or possible to assess using any kind of objective measure.

The performance measure enabled quantitative comparisons of the teams. The F-REX synchronized replay of all recorded sources was what enabled the actual performance analysis (Pilemalm, Andersson & Hallberg, 2008). Still, scoring was rather time consuming since most work had to be done manually. A remaining issue is then how to automate an objective and reliable performance measure in a dynamic, event-driven scenario such as this? The scenario was realistic, complex and provided learning opportunities since game control and HIC responded in accordance to the actions of the staff, but resource consuming in terms of analysis. Furthermore, a difficult issue when developing a performance measure is how to credit innovative solutions and creativity that the developers of the performance scale could not foresee? A demonstrator environment provides the ability to compare subjective and objective measures, which during these experiments was particularly useful when assessing situational awareness (based on experienced/actual jamming/CNO). Another advantage of using a simulated environment is that the situation can be manipulated in a controlled way. In this case, C2 warfare provided an opportunity to manipulate the participants' C2 ability. Due to the fact that the participants were subject matter experts; they were still able to recognize situations and use tools and tactics that they would use in a real setting.

Conclusions

What is C2 ability? Results of these experiments point to that the prerequisites which form the hypothesis used during these experiments are central aspects that need to be considered when trying to increase or protect staffs' C2 ability. The C2WD provided an environment in which C2 could be studied, in a more controlled way than in a real setting, but still a complex and realistic environment. Based on the results, it can be concluded that team aspects are central regarding the timeliness and flexibility in decisions, perhaps more central than that the situation is interpreted correctly. Development of an objective performance measure aided in comparing the teams, and a remaining challenge is to find a solution of how to automate such a measure, in order to be able to give immediate feedback to the teams and make analyses less time consuming.

Acknowledgments

The C2WD project was financed by the Swedish Armed Forces and the Swedish Defence Materials Administration. The Swedish Armed Forces also contributed to the project as experiment participants and domain experts throughout the development process. Apart from the authors of the paper, several people from the Swedish Defence Research Agency participated in the development of the demonstrator. Hanna Andersson, Pär Brännström, Ragnar Hammarqvist, Christer Lundstedt, Torbjörn Härje, Linus Hilding and Fredrik Mörnestedt conducted the main part of the development of the technical platform. Martin Castor and Jenny Lindoff contributed to the development of scenario, experimentation and methodology for assessing C2 ability. Several persons at Swedish Defence Research Agency have also been involved in the in-house development of the tools for data collection (Network-Based Observation Tool, NBOT) and reconstruction and analysis (F-REX) however the main contributors to this development are Dennis Andersson and Mathias Johansson. During experiments, Niclas Appleby conducted video documentation enabling experiment analysis and demonstrations.

References

Andersson, D. (2009). F-REX: Event-Driven Synchronized Multimedia Model Visualization. *Proceedings of The 15th International Conference on Distributed Multimedia Systems*, pp 140-145. September 10-12, Redwood City, CA.

Andersson, J., Malm, M. & Thurén, J. (2003). *Systemtilltro.* (In Swedish. English title: System Trust). FOI-R--1121--SE. Linköping: Totalförsvarets forskningsinstitut.

Atkins, P.W.B., Wood, R.E. & Rutgers, P.J. (2002). The effects of feedback format on dynamic decision making. *Organizational Behavior and Human Decision Processes*, 88 (2), pp. 587-604.

Beaubien, J., Baker, D. & Holtzman, M.A. (2003). How Military Research can improve team training effectiveness in other high-risk industries. *Proceedings of the 45th annual conference of the International Military Testing Association*.

Bolstad, C.A. & Endsley, M.R. (2000). Shared displays and team performance. *Human Performance, Situation Awareness & Automation Conference.* Savannah, GA.

Brannick, M., T., Salas, E., & Prince, C. (Eds.). (1997). *Team Performance Assessment and Measurement: Theory, Methods, and Applications.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Brehmer, B (1989). Feedback Delays and Control in Complex Dynamic System, Computer-based management of Complex Systems. *Proceedings of the 1989 International conference of the System Dynamic Society,* 99, pp. 189-196.

Brehmer, B. (1992). Dynamic Decision Making: Human Control of Complex Systems. *Acta Psychologica*, 81, pp. 211-241.

Cheah, M., Thunholm, P., Chew, L.P., Wikberg, P., Andersson, J. & Danielsson, T. (2005). C2 Team Collaboration Experiment - A Joint Research by Sweden and Singapore on Teams in a CPoF environment. *Proceedings to 10th International Command and Control Research and Technology Symposium: The Future of Command and Control,* June 13-16, McLean, VA. Command and Control Research Program (CCRP). Washington, D.C.

Davison, M. & Sireci, S. (2000). Multidimensional Scaling. In Tinsley, H. & Brown, S. (Eds.) *Handbook of Applied Multivariate Statistics and Mathematical Modeling*. San Diego: Academic Press.

Diamantopoulos, A. & Siguaw, J.A. (2000). *Introducing LISREL*. London: Sage

Endsley M., Bolte B. & Jones D.G. (2003). *Designing for situation awareness. An approach to user-centered design.* New York: Taylor & Francis.

Endsley, M.R. (2004). Human Factors Issues in Synthetic Vision Displays: Government, Academic, Military, and Industry Perspectives. *Proceedings of the Human factors and Ergonomics Society* 48th Annual Meeting.

Hammervik, M., Klum, P., Lif, P., Johansson, B., Castor, M. & Tydén, L. (2009). *Slutrapport LKS Metodutveckling*. (In Swedish. English title: Final Report LKS Methods development). FOI-R-2843--SE. Linköping: Totalförsvarets forskningsinstitut.

Hammervik, M., Lindoff, J., Castor, M. & Tydén, L. (2007) *Studying the Effects of Command and Control Warfare on Command and Control Performance.* Proceedings of the 24 International Symposium on Military Operational Research (ISMOR), August 28, 2007.

Höglund, F., Berggren, P. & Nählinder, S. (2009). *Using shared priorities to measure shared situation awareness*. FOI-R--2791--SE. Linköping: Totalförsvarets forskningsinstitut.

Janis A. Cannon-Bowers, J. & Salas, E. (1998). Team Performance and Training in Complex Environments: Recent Findings from Applied Research. *Current Directions in Psychological Science*, 7(3), pp. 83-87.

Jöreskog, K. & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Chicago: Scientific software international.

Klein, G. Arasanu, J., Calderwood, R. & Zsambok, C. (1993). *Decision Making in Action: Models and methods*. New Jersey: Ablex Publishing Corporation Norwood.

Lee, D.J. & See, K.A. (2004). Trust in automation: designing for appropriate reliance. *Human Factors,* 46(1), pp. 50-80.

Lim, K.H., O'Connor, M.J. & Remus, W.E. (2005). The impact of presentation media on decision making: does multimedia improve the effectiveness of feedback? *Information and Management archive,* 42(2), pp. 305-316. Amsterdam: Elsevier Science Publishers B. V.

Matthews, M.D., Pleban, R.J., Endsley, M.R. & Strater, L.G. (2000) Measures of infantry situation awareness for a virtual MOUT environment. *Proceedings of the Human Performance, Situation Awareness and Automation: User-Centered Design for the New Millennium*. Savannah, GA: SA Technologies Inc.

NATO. (2004). *NATO Code of Best Practice for Command and Control Assessment.* NATO RTO TECHNICAL REPORT TR-081. NATO C2 Assessment Knowledge base. Retrieved January 31, 2011 from http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-081///TR-081-$$ALL.pdf

Pilemalm, S., Andersson, D. & Hallberg, N. (2008). Reconstruction and exploration of large-scale distributed operations—Multimedia tools for evaluation of emergency management response. *Journal of Emergency Management*, 6(4), pp. 31-47.

Rasmussen, J., Brehmer, B. & Leplat, J. (Eds.) (1991). *Distributed Decision Making Cognitive models for cooperative work.* West Sussex: John Wiley & Sons Ltd.

Riley, J.M., Kaber, D.B. & Draper, J.V. (2004). Situation awareness and attention allocation measures for quantifying telepresence experiences in teleoperation. *Human Factors & Ergonomics in Manufacturing*, 14 (1), pp. 51-67.

Svensson, J. & Andersson J. (2006). Speech Acts, Communication Problems, and Fighter Pilot Team Performance. *Ergonomics*, 49(12&13), pp. 1226-1237.

Thorstensson, M. (2008). *Using Observers for Model Based Data Collection in Distributed Tactical Operaions*. Lic. thesis no. 1386. Linköping University, Institute of Technology.

Tydén, L., Brännström, P., Andersson, H., Lundstedt, C., Hammervik, M., Klum, P., Härje, T., Hammarqvist, R., Hilding, L. & Mörnestedt, F. (2009). *Användarhandledning LKS Teknik och Metoder*. (In Swedish. English title: User Guide LKS Technology and Methods). FOI-R-2842--SE. Linköping: Totalförsvarets forskningsinstitut.

Young, F. (1985). Multidimensional Scaling. In Kotz, S & Johnson, N. L. (Eds.) *Encyclopedia of Statistical Sciences*. Volume 5 John Wiley & Sons. Retrieved January 31, 2011 from http://forrest.psych.unc.edu/teaching/p208a/mds/mds.html