14th ICCRTS

"C2 and Agility"

AGILITY CHALLENGES AND SOLUTIONS FOR C2 SOFTWARE

Topic 9: C2 Architectures and Technology

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14th ICCRTS: C2 and Agility

AGILITY CHALLENGES AND SOLUTIONS FOR C2 SOFTWARE

Abstract

This paper aims to discuss how the six dimensions of agility could be observed in C² software, regarding the Brazilian Army experience. The Brazilian Army, as well as other armies around the world, demands Command and Control systems that are able to work in different environment and conditions, to allow integration with other organizations, including non-military, and to respond properly and timely in all situations. In order to address these requirements, C² software development faced the need for refactoring and evolution. The implementation of a generic framework and a plug-in infrastructure appeared as a solution to improve agility in C² applications. This approach promotes native interoperability between C² software and weapons systems, simulation and decision support software, both civilian and military in all levels. These changes also intend to provide COP and UDOP capabilities to the decisionmaker and to enable non-centralized and collaborative software development. An experimental approach regarding an intrusion automatic alert system will be described, within the agility and situational awareness improvement context.

Keywords: Situational Awareness, Framework Development, COP, UDOP, C2, Software

1. Introduction

1.1. The C2 in Combat Project

Although the technological solution solely cannot classify an organization as agile, it contributes strongly to do that in such manner that without it, it is not possible to an organization to become agile.

The current tactical C2 development project in the Brazilian Army C2 in Combat (C2Cmb) was started in 2003 with the objective to improve the agility of Brazilian Army operational performance. Two major segments compose this system: the C2 software and the telecommunications infrastructure.

The C2Cmb software has been developed under directive that its distribution must be free of any licensing costs. The result is that it is based on open source free database and GIS software integrated into a user interface that can run on either Windows or Linux platforms.

It has been completely developed by Army personnel and is configured to operate on a distributed basis (i.e. no centralized servers being employed), even over HF networks.

For the C2 nodes exchange data, there is a diffusion protocol that handles information addressed to a specific node in order that only the needed data flows through the network, minimizing the amount of traffic, and the available information is well segmented, which minimizes the impact if a node fails or falls down under control of the enemy. The information that arrives at a node is handled by one master machine and the replication protocol ensures each computer gets a copy of the same information as all other computers within the node.

This article will focus over the C2Cmb software and will not cover the telecommunication solution, as well as other defense tools available for the Brazilian Armed Forces.

1.2. The Brazilian Army current issues

To become efficient while not engaging defiant military threats. That’s the main issue that Brazilian Army, as well Navy and Air Force, faces in the 21st century.

The wide territory associated to the valuable resources spread out through the whole surface as well territorial sea impose the necessity to be aware of any threat as quick as possible so the Brazilian Armed Forces can be employed in a fast and efficient manner. Any solution for this issue passes through the telecommunications infrastructure, to conduct the information as fast as the scenario demands, and the tools to generate, to assembly and to present the threaten scenario to the decisionmaker so he can issue suitable and clear orders to the action elements and those ones be able to gather all necessary information to perform their neutralization tasks.

Besides the military issue, the non-military operational scenarios, like natural disasters support and law and order guarantee operations, demand a command and control system that is flexible to comply fast scenario changes, robust to operate continuously both within the city and the jungle, and be able to adapt from a simple scenario that employ only special forces teams, for instance, to a complex scenario employing complete brigades as well Air Force and Navy maneuver elements.

Questions about how well prepared the troops and the commanders are or how to measure the situational awareness level in combat are the needs that motivate the evolution of the C2Cmb software.

The remainder of this paper is organized as follows. Section 2 presents the C2Cmb software evolution concepts overview, focusing on framework and plug-ins development. Section 3 describes the relationship of C2Cmb software and the six agility aspects. Section 4 presents the Intrusion Automatic Alert System as a practical example of the new development capability that becomes available with the new C2Cmb development approach, contributing to improve agility. Section 5 is the conclusion of this paper.

2. The C2Cmb Software evolution to match complex endeavors requirements

2.1. Motivations to change the project perspective

C2Cmb was firstly conceived to be used only for conventional military operations in tactical level, but the variety of missions and tasks performed by Brazilian Army forced a change of this perspective. C2Cmb software should be able to deal with different sorts of missions, each of them requiring specific features and resources. The C2Cmb should be able to fulfill both issues, in order to match the Brazilian Army everyday challenges.

Since the new perspective represents a change from rigid hierarchical communication structures to edge ones, the C2Cmb project also had to face the need for improve data exchange and replication mechanisms. It leads the developers to find more suitable solutions to deals with different configurations of data flows, depending on the nature of the mission.

2.2. The new features of C2 in Combat

In order to enable working with various kinds of military missions in different manners, the development of a generic framework and a plug-in infrastructure have been proposed, similar to Eclipse Platform concept [1]. The choice to load or not any plug-in will relies on the nature of the mission and on the environment and role of the user.

The proposed architecture also allows the integration between C2Cmb and other existing or future software projects of Brazilian Army, such as weapons systems, simulation and decision support software. The generic framework may be used to build software that will get native interoperability with C2Cmb. These systems' integration will improve greatly the agility of C2 processes.

To solve the communication issue, it was decided to adopt internodes diffusion mechanisms based on MIP DEM specification [2]. This mechanism is based on the concept of publishing and signing military information. A node may publish to other chosen nodes operational information groups, like, for instance, the enemy information it has gotten. One of the chosen nodes may sign this information and receive updates about it. An “intranode” replication mechanism also appeared as part of the solution to achieve the desired agility issues, as will be discussed later on this paper.

3. Agility in C2Cmb Software: how the six aspects are perceived through the software concepts

Information is essential to perform a successful task. As task complexity grows, more information is needed and that must arrive as soon as it is generated to the decisionmaker in all levels so the orders can reach the edge faster. However, flooding the decisionmaker with thousands of information will not help him to complete the task successfully. This passes through the *information quality position concept* which is discussed in [3]. *The quality of information position is in the information domain and hence is concerned about the quality of data and the ability to turn data into high quality information* [3].

This is the foundation of the force agility, which is necessary but not sufficient to accomplish the assigned mission. An agile information flow is necessarily conducted by an agile C2 system (personnel and their supporting information systems and decision aids), which together agile individuals and organizations, provide synergy of the six dimensions of agility to become an agile force and allow decisionmaking to reach the operating environment (Figure 1).

That is the motivation for current C2Cmb software development approach and the way it meets this requirement will follow.

3.1. The six aspects of agility

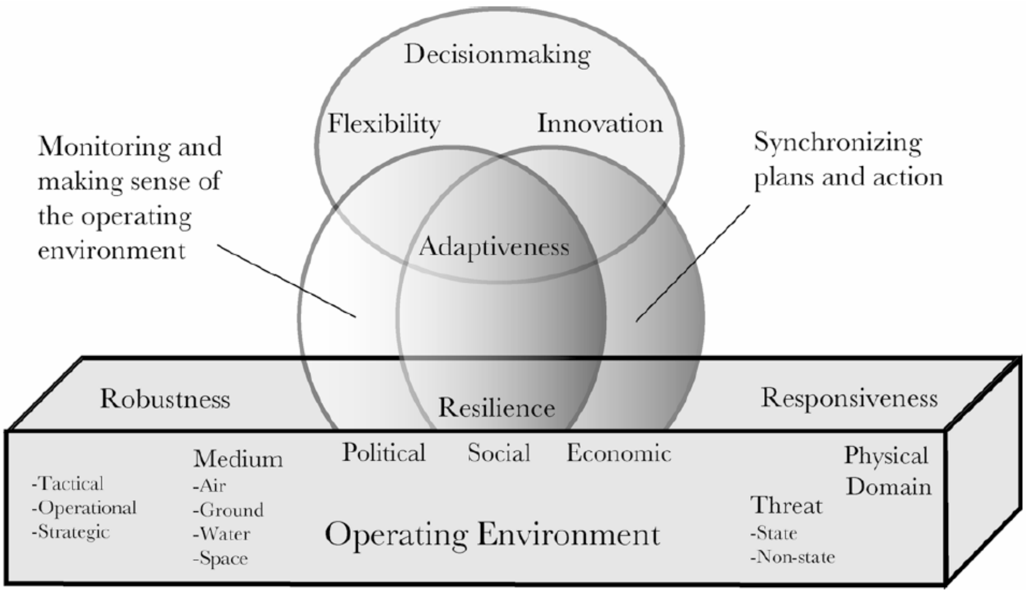

Figure 1 - The Six Aspects of Agility in the Domains of Warfare[1]

Agility is the synergistic combination of robustness, resilience, responsiveness, flexibility, innovation, and adaptation. Each of these attributes of agility contributes to the ability of an entity (a person, an organization, a coalition, an approach to command and control, a system, or a process) to be effective in the face of a dynamic situation, unexpected circumstances, or sustaining damage [4].

Robustness[2]

Robustness is the ability to maintain effectiveness across a range of tasks, situations, and conditions, spanning the spectrum of conflict, operating environments, and/or circumstances. Usually it is the first casualty when operational concepts, C2 systems and military forces are optimized to face a particular threat. The reason for this lack of robustness is because if the threaten scenario changes (and that can occur quickly and frequently), the whole set has high failure probability.

Focusing on C2 system, to keep the robustness under all threatening situations, it must be able to change its configuration as fast as the scenario changes. This means that the C2 systems must be able to load new components suitable to the threat change and discharge the old ones that are not applicable to the situation.

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[1] Alberts, *Power to the Edge*

[2] All six aspects definitions were transcribed from [5].

Resilience

Resilience is the ability to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment. Under the Information Age approach the command centers are at less risk because they are distributed, senior commanders are more mobile, the communication systems are networked, allowing multiple paths for information flow, and the collaborative decisionmaking improves both the quality of the decisions and the understanding of the reasons behind command intent and specific decisions. Besides, developing richer information and sharing it more broadly reduce the casualties and platform losses, reducing even the fratricide losses.

Resilience also contributes to better performance for some commanders under pressure and stress because the information availability allow them to see cause and effect as arising from local conditions, see themselves as having more control over events than others and see problems as temporary rather than permanent. For such kinds of commanders, the C2 systems must adjust quickly in the event of a misfortune or damage, so they can provide fast decisions.

Bottom line, the more resilient C2 system will be the one that can withstand greater pressure and larger shocks and is disrupted for a shorter period of time.

Responsiveness

Responsiveness is the ability to react to a change in the environment in a timely manner. While resilience deals with the ability to recover from a crash, for C2 systems, responsiveness deals with the speed in which this recovery happens.

Responsiveness of forces is further increased because of their ability to conduct simultaneous and continuous operations– not just hitting harder, but also allowing the adversary less time to build situation awareness and develop countermeasures. Then, C2 systems must provide means to see more opportunities earlier and allow the forces to exploit them more quickly, more efficiently, and more effectively.

Flexibility

Flexibility is defined as the ability to employ multiple ways to succeed and the capacity to move seamlessly among them. It is related to the capability to employ a variety of synergistic efforts to accomplish a mission efficiently.

It can be viewed as composed by two main parts. The first one is the planning, when all possible evolutions of a scenario must be considered and analyzed. By doing so, less situations can be forgotten which means that the decisionmaker can adjust the selected action if an unexpected fact occurs. The second one is the monitoring course of action, in order to provide the decisionmaker with any information deviation of the planned action. As soon the C2 systems provide such information, the commander can adapt the plan.

Let us consider a Special Forces infiltration operation. The team can be transported to the operation area by car, helicopter or by boat or launched by aircraft. All possibilities for each option must be considered during the planning phase, with positive and negative aspects. Once one action is chosen, it is necessary to monitor the course of action in case, for instance, the airspace becomes hostile and it will be necessary to change from aircraft transportation to car transportation. Such information must arrive to the decisionmaker sooner and precisely, even under electronic interference. That´s the C2 system flexibility attribute.

One commander that considers only one course of action and decides solely for air transportation would not accomplish the mission, even if the C2 system is flexible to provide information under adverse conditions.

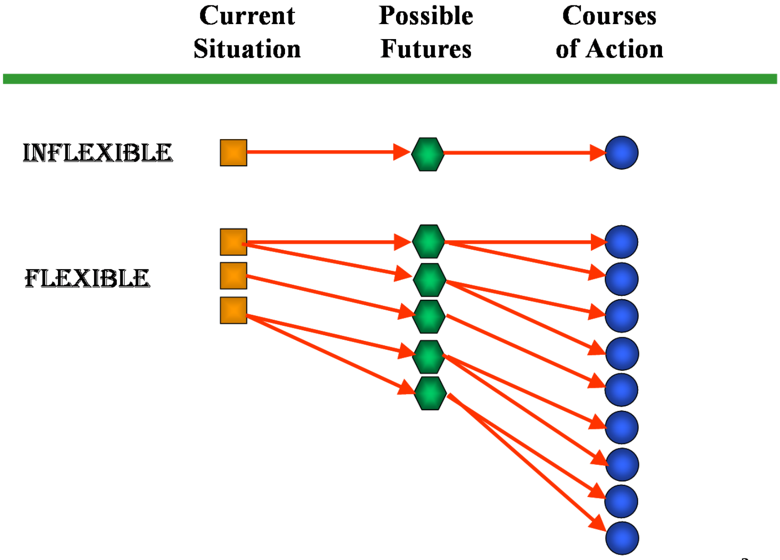

Figure 2 - Flexibility creates more options in a given situation[3]

Innovation

Innovation is the ability to do new things and the ability to do old things in new ways to achieve desired ends. It involves the ability to learn over time about missions and operational environments and to take advantage of the lessons learned to create and maintain competitive advantages.

That is the point where war games and combat simulation meet C2 systems. By storing data gathered during campaigns as well as decisions made by commanders and playing them back on simulation platforms possible alternatives can be analyzed and taught in order that they can be employed in the future if that situation happens again.

Adaptation

Adaptation is the ability to alter force organization and work processes when necessary as the situation and/or environment changes.

The capacity to change the organization and business rules by which we operate can make us more effective and efficient when dealing with different types of missions.

To become more effective and efficient when dealing with different types of missions an agile force must be able to change its organization and business rules.

[3] Alberts, *Power to the Edge*

Under this concern, C2 systems must be capable to attend many types of needs, military and non-military, and adapt themselves fast from one scenario to another.

3.2. Mapping the six aspects of agility into C2Cmb proposal

This section presents the perspective about how the six aspects of agility previously described could be perceived in C2Cmb project. It is straighten related to the new framework approach that was adopted to C2Cmb software evolution development.

Robustness

C2Cmb is designed to be robust, since it must be employed in a large range of military missions, from conventional warfare to complex endeavors operations. In order to fulfill this requirement, without losing performance or being "user-unfriendly", a plug-in infrastructure was implemented to allow users to load only the plug-ins which are relevant to accomplish the mission anytime they needed to. For instance, if the user is engaged in a humanitarian mission, plug-ins that provide data exchange between C2Cmb and civilian entities involved are loaded. These plug-ins, however, should be useless in a combat simulation exercise, which would require another specific set of plug-ins.

Resilience

C2Cmb has some strategies to recover from environmental damages and to avoid enemies' threats. The "intranode" replication mechanism assures that all information produced and received by a computer in a node reaches every other computer within the same node. Instead of a client/server approach, a decentralized reliable distributed architecture was conceived. It means that, if a computer is lost, it can be replaced and be synchronized with the others. Intranode and internode data reception is guaranteed, because C2Cmb is able to detect packet losses and asks for retransmission.

Figure 3 presents the conceptual view of the intranode and internode data handling.

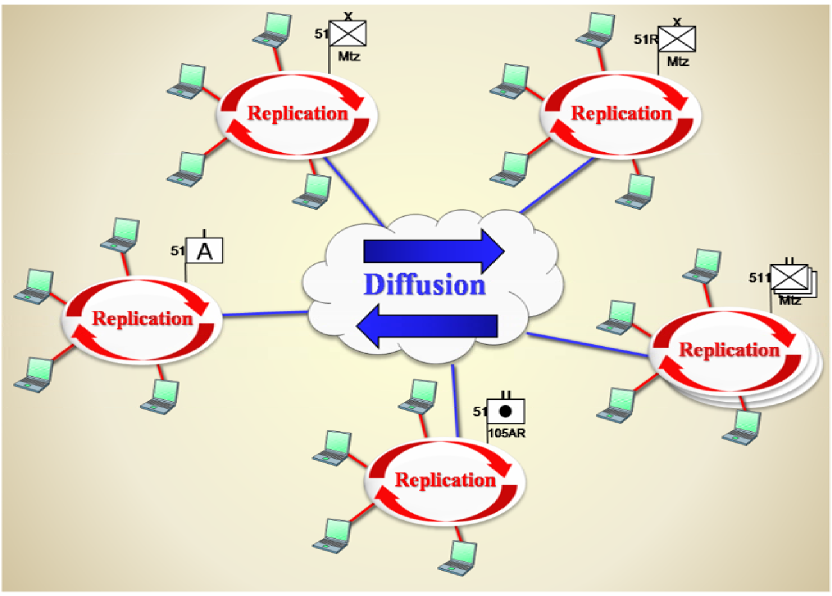

Figure 3 - C2Cmb Distributed System Concept

Besides, many security features implemented in C2Cmb contribute to assure resilience, such as authentication mechanisms, certification, cryptography, fast data destruction (in case of the imminence of being captured by the enemy), etc.

Responsiveness

To react in a timely manner could be considered as the most important concern in C2Cmb project since its early days. The first preoccupation we got was the transmission speed. It leads to the design of data packages short enough to be timely effective transmitted even by low rate means, such as HF radios.

There is a consensus that no matter how many resources and features a C2 system has, if relevant information does not reache its destination early enough to enable a proper reaction, the system is useless. That is why responsiveness is so fundamental and, in order to achieve it, there is a strong effort to conceive an effective architecture, to implement multicast transmissions, to choose the most appropriate algorithms, the best programming practices and to work closely with end-users to get their impressions and to build some metrics.

The adoption of an internode data exchange mechanism, based on MIP DEM specification [2], will improve responsiveness, since the amount of information to be transmitted tends to decrease because users will probably be more selective about the information they sign and, consequently, receive. The UDOP (User Defined Operational Picture) achieved as consequence of information signatures and loaded plug-ins will help users react faster to information inputs. Our concerns in C2Cmb also include experiments to develop user-friendly graphical interfaces and some features like the Intrusion Automatic Alert System that will be described later on Section 4.

Flexibility

Plug-in architectures are naturally designed to improve software flexibility. Each plug-in gives the software the ability to perform different tasks or has a particular appearance. It may contribute to develop features to improve the flexibility aspect in C2Cmb that already has the capability to support planning activities which are the basis to achieve the ability to create and analyze different scenarios, helping the Army to accomplish the concept of Effects Based Operations.

According to what was described on section 3.1, the C2Cmb planning capability allows the planners to elaborate and analyze all possible scenarios based upon the current situation, exercising the prediction of possible futures, taking advantage of artificial intelligence (AI) plug-in, and watch the courses of action. Any deviation from the plan can arrive to the decisionmaker through the software even under a strong electronic warfare scenario.

The commander intent can also be followed by sharing all possible alternatives analysis and in-work planning to the lowers commanders so they can have more time available to prepare for action.

Flexibility increase is straightly related to the ability of rapid recognition of changes in the battlespace. Within this approach, an intrusion automated alert capability added to the C2 system would be desirable to improve flexibility by anticipating possible threats and that is the motivation of the system development described in section 4 of this paper.

Figure 4 is a screen capture of C2Cmb employed by Brazilian Army in Haiti, under MINUSTAH (United Nations Stabilization Mission in Haiti) peacekeeping operation. The software interface and capabilities are the same as presented on Figure 5, which is a screen capture of the software prepared during a class at Army High Staff School, showing that user can build operational elements accordingly to both conventional and non-conventional scenarios.

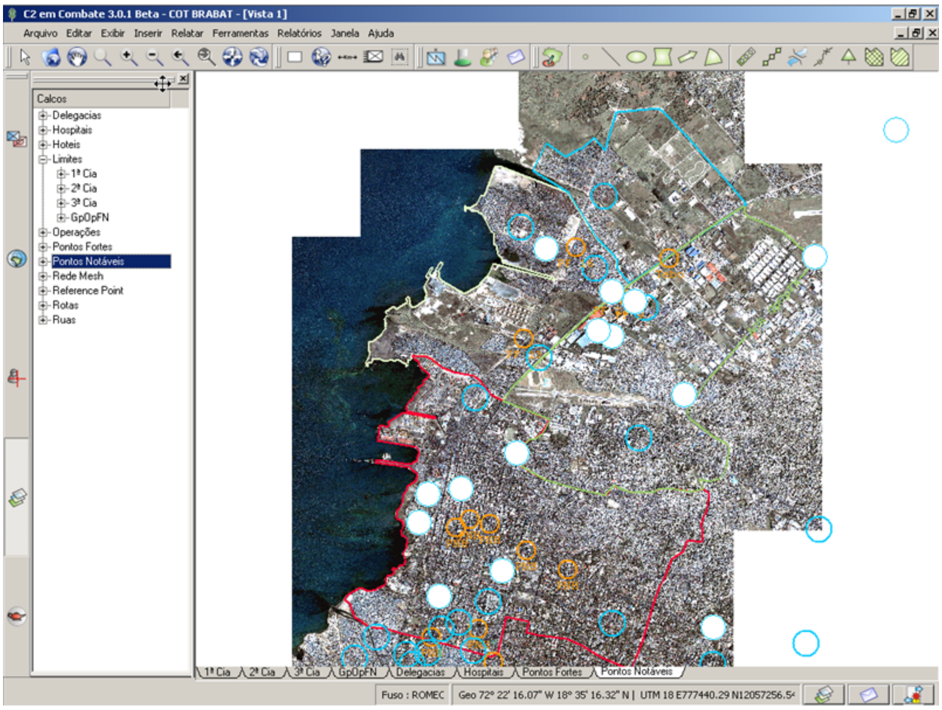

Figure 4 - Screen capture of peacekeeping operation in Haiti with C2Cmb

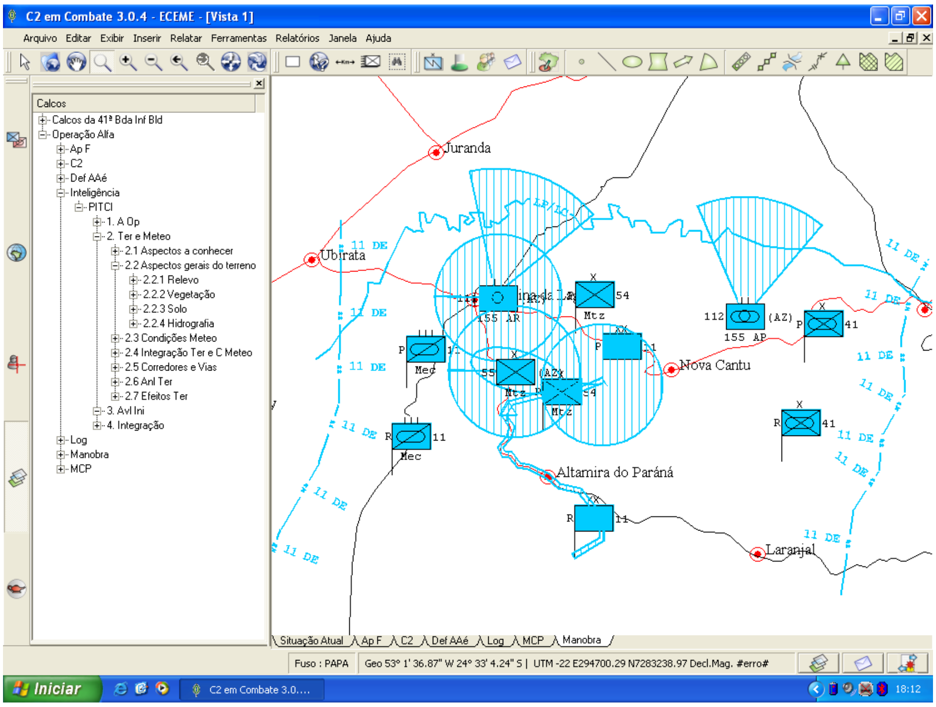

Figure 5 – Screen capture of conventional combat class planning with C2Cmb

What is expected as part of the overlays and AI plug-in tools and capabilities of C2Cmb is that multiple futures can be foreseen, allowing a rich set of actions that can be taken, also increasing flexibility.

Innovation

The plug-in architecture aims to assure the interoperability of C2Cmb and other simulation and decision support systems in order to allow the analysis and test of different courses of action and, consequently, promoting an improvement of the innovation aspect.

C2Cmb is already integrated to simulations systems, via plug-in, which allows post-action analysis of previous campaigns and to exercise alternate possibilities on a "what if" basis, since C2Cmb can maintain all information gathered in missions in each point of time, allowing it to be used as a learning resource.

Besides, the post-action analysis conclusion regarding the best option of previous campaign can be saved in the database and loaded every time such scenario rises to the troop, denying to the adversaries clues based on our previous behaviors.

Adaptation

C2Cmb does not presume fixed actors, roles or network structures. The end-user is responsible for establishing their responsibilities and hierarchical relationships, in accordance to the planning orders. It makes the system very adaptable, but demands the user to develop his situational awareness and, in a larger perspective, improve his understanding of Command and Control. Again, the intrusion automated alert capability development added to the C2 system was expected to improve situational awareness, allowing the adaptation capability to be improved, as presented on next section of this paper.

C2Cmb plug-in architecture also contributes with the ability to be adaptable to each situation or condition. Plug-ins may change software interface appearance and behavior in order to be more suitable to a particular condition, such as the use inside a military vehicle or inside a headquarter building, for instance, or does not load electronic warfare plug-in if the scenario does not demand it. This capability has been tested in many exercises and proved to work acceptably.

4. Intrusion Automatic Alert System

The use of networked computers to enhance agility in the C2 has opened new possibilities. Data can be analyzed by computers and results displayed to leaders, providing them better information on which to decide. Leaders can be provided with immediate feedback about their performance. One promising technology would be a computer system to monitor the data stream and provide alerts when critical events occur to ensure they are not missed by the operator [6].

As well as the troops gain more experience in net-centric digital C2 systems, more functionality is required and added to the systems. Features such as the automated alert system, described above, can help direct the user`s attention to important events and increase the Situational Awareness (SA).

4.1. The Conception

An automated alerting system is a tool used to monitor the data and to provide alert when critical events occur, with the purpose to guarantee that these are not forgotten by the operator. In fact, an important consideration is that operators who visualize computer screens can fail in detecting changes that occur on those displays, called phenomenon change blindness.

Change blindness tends to occur concurrently with various types of visual transients such as icon movement, screen flashes or eye blinks. In addition, operators may fail to detect changes if they are performing other tasks or working in one determined level of zoom and these alterations to happen outside of its area of vision. Individuals tended to detect changes in icon appearance, disappearance, and color changes but had more difficulty detecting changes in icon type and movement, particularly if the icon was in the screen periphery and the movement was small.

The concept of change blindness is related with the system of alarms of two forms. First, alerts can call the attention for critical events that the operator of the system is not monitoring. Second, alerts can “blind” the operator by capturing his attention at inopportune moments. Both the effects influence the SA of the operator.

The C2Cmb software can store all the inserted information, also with an evaluation of the information source, but it does not possess an automated alerting digital system.

During the graduate program in the Aeronautical Institute of Technology (ITA) in 2009, a new software component was developed to be connected to the C2Cmb. The so-called Intrusion Alerts Automatic System (SAAI) adds automatic alerts functionalities to the software to give support to Post-Action Analysis (APA) of operational exercises. SAAI allows configuring the types of alerts to be monitored for each specific machine. It also allows the user to decide when the alert must be gone off. For example, using the SAAI a unit can be informed when an enemy aerial vector comes closer (Figure 6 - SAAI - Alert example).

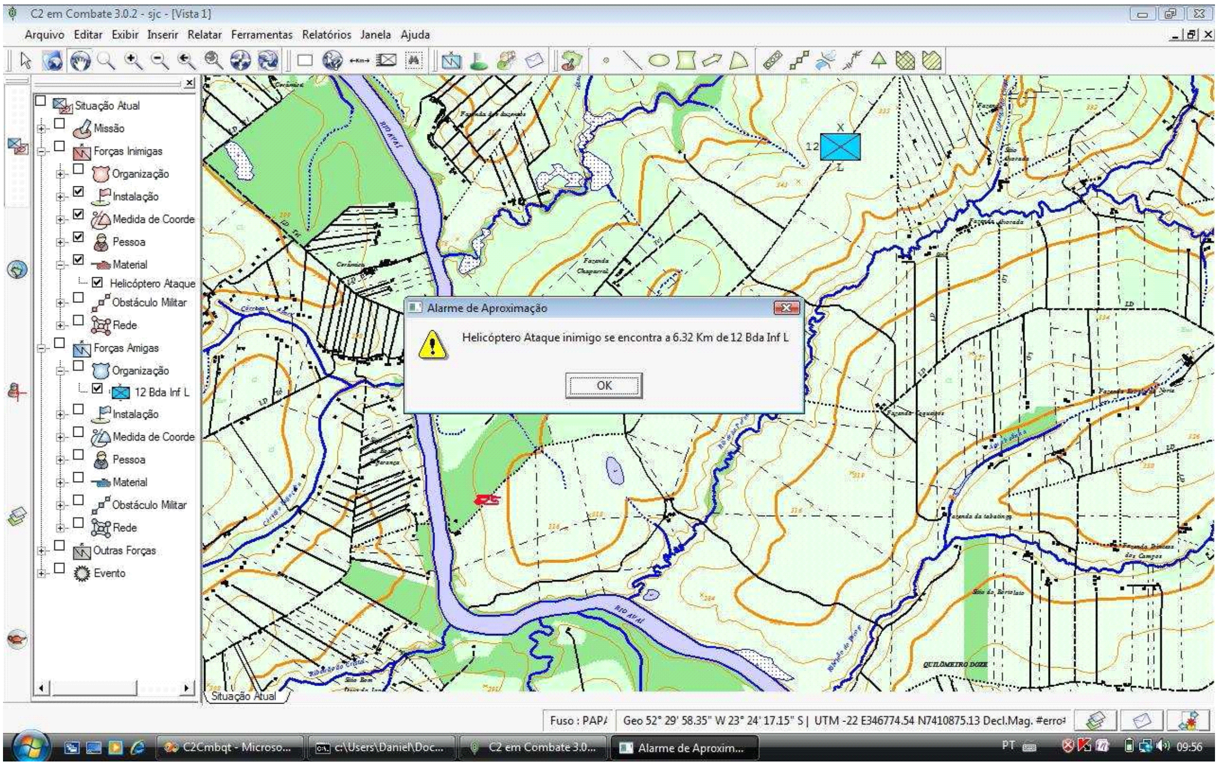

Figure 6 - SAAI - Alert example

SAAI provides information in text format and can store the operator decisions in reply to one alert. The user can also not answer the alert and keep it, or erase it. SAAI keeps a register that allows the user recoup an alert kept or data for the APA. The operator can keep an alert during a period of high workload and subsequently recoup it to see if it still remains, that is, if the situation that stilled to the alert continues.

The software component SAAI, in this first phase of development, fits in the layer of presentation in C2Cmb software (Figure 7). It uses the services of the business layer provided by the C2 component.

A user can enable or disable the functionality of automatic alarms. It can still configure the options amongst the five types of available alarms and choose which unit he or she desires to monitor.

Once the functionality of alarms is on, all reports of new information that the machine creates or receives pass by the alarm system to evaluate the information and, if necessary, emit an alarm. Then an event is thrown.

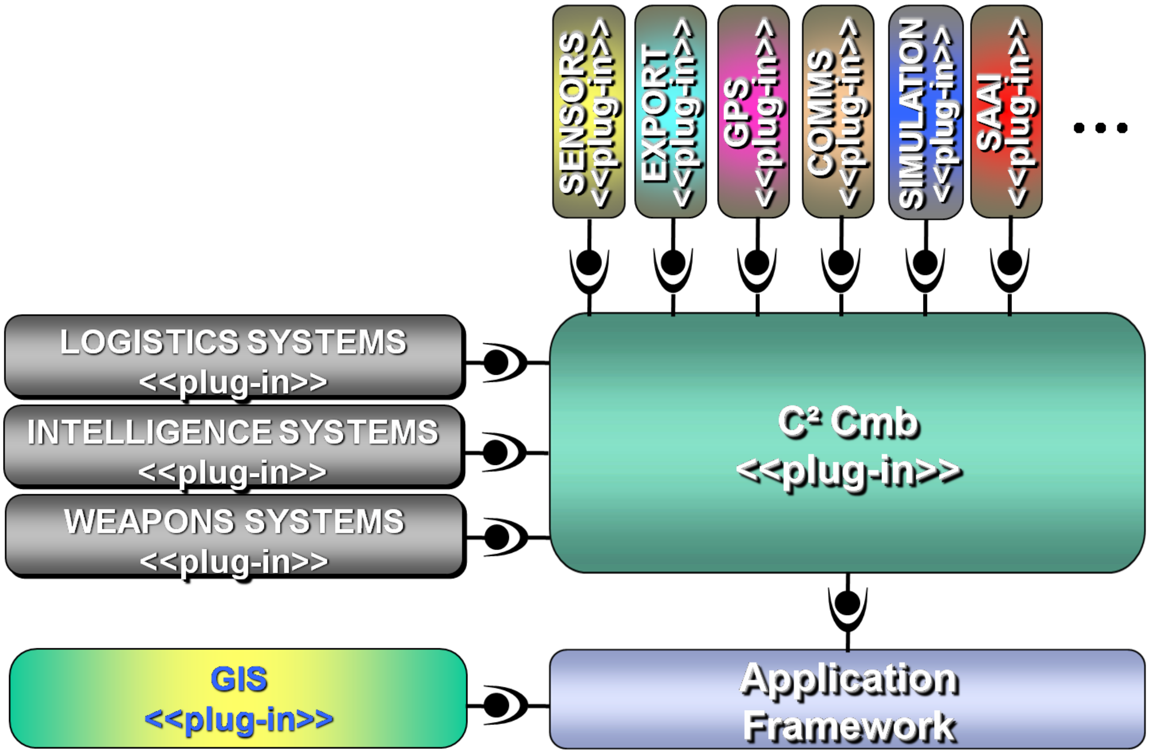

Figure 7 - SAAI component in the C2Cmb architecture

On a second development phase, some types of alarms are followed by a window type checkbox where the operator can inform the action taken for that alarm.

The main reason for SAAI development was for serving as a tool for experiments carried through in a graduate program that is studying the agility and effect of automatic feedbacks in net-centric C2 systems. The C2Cmb software is being used to simulate scenarios of tactical operations and SAAI is used to evaluate its performance.

4.2. The Experiment

Automated feedback systems, in other areas, have shown that automation can, paradoxically, contribute to the reduction of SA. During high stress or high workload periods, alerts may actually become intrusive, and responding to them can increase workload, shift the operator's attention consequently reducing agility. This raises the question of whether immediate feedbacks enhance or intervene in the agility.

An experiment that informs as SA varies when we use a system that generates automatic alerts was conducted. SA and agility in C2 are related intrinsically inside the Decision Making loop. While SA gives attention to the actions of environment perception and comprehension for better Orientation in the decision making process, the aspects of the agility are for all phases. Thus the experiment used to measure SA can also be applied to the agility.

Fifteen Brazilian Army infantry soldiers with no prior experience with C2Cmb software have participated in an experiment that used this software and its SAAI component. The mean age of the selected military was 37.2 years (standard deviation = 4.2) and they had about 17 years (standard deviation = 4.6) of military experience. They were both sergeants and officers. The experiment aimed to propose some simulated scenarios in a net-centric system to the military and evaluate their reactions and SA level.

The simulations presented experimental scenarios on a map showing a digital military operation with locations of friendly units, enemy units and battlefield graphics such as phase lines, unit boundaries, obstacle belts, etc.

A simulation of SAAI ran concurrently with the C2Cmb task during experimental trials. The current experiment employed SAAI alerts triggered by five significant events: unit approaching a minefield, receipt of an enemy report, a new friendly unit appearing on the display, approach of enemy units, or a unit approaching a nuclear- biological- chemical (NBC) contaminated area. The SAAI system has a number of other features which were not used for this research as they would have added unnecessary complexity to the experiment. This experiment employed SAAI textual alerts, but it did not include graphical alerts or other capabilities. Further, participants were required to interact with the alerts to remove alerts from the screen. The features used were the visual alerts.

Workload was varied by manipulating task difficulty. In one C2Cmb scenario, task difficulty, defined as the number of significant events (i.e., minefield, enemy report, etc.) per time interval, was low whereas in another scenario it was high. A low difficulty condition had in average 1 event every 30 seconds (10 total events). The high difficulty condition had in average 1 event every 20 seconds (20 total events). The order of significant events was randomized with the constraint that each type of event appeared equally as often as the other events.

Participants' SA was measured using the Situation Awareness Global Assessment Technique (SAGAT) [7]. Example queries included recalling the approximate number of friendly units currently on the display and drawing conclusions about which objective the commander's unit (icon) is heading towards.

Participants then completed two experimental sessions of approximately 12 minutes each.

During the sessions they were asked to view the C2Cmb display and monitor it for significant events. For one session, alerts were enabled, while for the other session alerts were disabled. The conditions (alerts enabled or disabled) and scenarios (which of the programmed C2Cmb scenarios they observed) were counterbalanced, creating four possible orders.

The participants were asked on several aspects of the situation executed. All the SA levels were evaluated. They had approached the situation; the mission of the troop and its subordinated elements; the available data on the enemy; the half employees in the maneuver and the peculiarities of the land.

The SAGAT performance results are displayed in Figure 8. We examined the C2Cmb scenarios with low and high workload. In the vertical axle it meets SAGAT scores of the questionnaires in percentage. Both trials were evaluated with and without alerts.

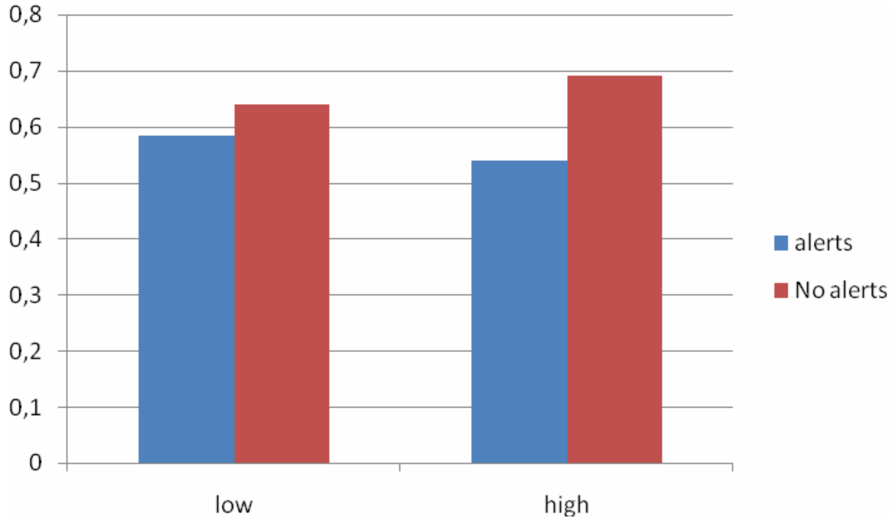

Figure 8 - SAGAT performance

There are slight differences between the results in function alerts conditions in low workload. The results indicated that the two scenarios did not significantly differ in SAGAT performance. However the SA was different when the workload was more perceivable. There was a significant effect for task difficulty. However, the main effect for alerts and the interaction between alerts and task difficulty were not significant. This result should not be necessarily interpreted as providing an advantage on the no alert condition.

Alerts are important in bringing critical tactical situations to the attention of operator and users of networked C2 systems, however, attention must be given to the relationship between workload and agility to enhance SA. In the current experiment, task difficulty was operationally defined in terms of the frequency of occurrence of events presented to the participants via the display.

Parameters	*With Alerts*	*Without Alerts*
Mean	0,538571	0,691429
Variance	0,017275	0,022552
occurrences	14	14
Variance group	0,019913	
Hypothesis	0	
df	26	
Stat t	-2,86592	
P(T<=t) one-sided	0,004064	
t critical one-sided	1,705618	
P(T<=t) two-sided	0,008129	
t critical two-sided	2,055529	

Table 1 - T-test: High Workload

Carrying through a T-test in the sample, under high workload (Table 1), we can affirm with a confidence interval of 95% that the means are different. It means to say that, with alerts system working, the SA was lesser.

We can raise two causes that had contributed for this conclusion. The first one is related to the operator´s profile that took part of the experiment, which was of a military with many years of experience, expert in its functions and that had never used the program of decision making. The alerts system for this profile of user was negative; this kind of operator did not work well with a system that it did not know. The second cause was the interaction human-computer. The alerts sometimes confused the accompaniment of the situation and shift the operator's attention. When alert one appeared, the operator concentrated itself in that event and lost temporarily the general vision, mainly with high workload.

At last, in spite of the real effectiveness of the alert system, the experiment using the SAAI served to confirm the aspects of the agility of the C2Cmb program; the fact of a system as the SAAI be implemented as one plug-in in another environment development totally distinct of the main program proved flexibility, responsiveness and also the innovation. The adaptation was identified why the C2Cmb also can be used as a tool of cognitive evaluation of C2 systems operators. The construction and execution of the experimental setup had been sufficiently satisfactory thus demonstrating the robustness and the resilience of the system.

5. Conclusion

This paper presented some aspects of the current development of Brazilian Army C2 software, named C2Cmb. We have described the framework and plug-in approach and the reasons for the software development change.

We also described the six aspects of agility and how they are perceived through the software concepts, by mapping them to the capabilities that the new development provides to the final product.

Finally we presented a practical example of how the new development concept allows the C2Cmb agility measurement by adding a component named Intrusion Alerts Automatic System (SAAI) that was employed in an experiment to measure the Situational Awareness level with and without alerts.

This SAAI development proved that the plug-in concept is technically efficient and spanned C2Cmb capabilities by adding intrusion detection features that were schedules to be added to the software only in future versions, mainly because there was no testing result available that demonstrate the feature will not jeopardize the SA, instead of improving it. Surprisingly, first results proved that with low workload, there is no benefit to use or not alert capability to improve SA. However, and that was the surprise, with high workload, SA was decreased when alerts were on. More tests will be run, but first analysis results showed that automated alert system should be used under very particular situation and not as a SA improvement tool.

We believe that the so-mentioned changes in C2Cmb project represent a great opportunity to evolve in many aspects, especially in terms of matching agility with present issues. The plug-in architecture encourages non-centralized and collaborative software development, which may accelerate the incorporation of new features and naturally expand the scope of the project, in order to better fulfill the C2 needs in modern warfare.

Some agility aspects such as flexibility and innovation may be more explored and many plug-ins could be developed to achieve better results in these directions. In fact, we understand that our greatest challenges involve the users because, as in other armies in the world, the development of a C2 culture, which includes the proper dealing with agility issues, is the main goal to achieve. C2Cmb is focused to help its users to effectively apply their knowledge in order to accomplish any kind of military mission.

Future works will present and discuss C2Cmb integration issues to simulation systems, sensors systems and reconnaissance (UAV) systems.

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7. Glossary

AI
: Artificial Intelligence

APA
: Post-Action Analysis

C^2Cmb
: Command and Control in Combat

COP
: Common Operational Picture

DEM
: Data Exchange Model

ITA
: Aeronautical Institute of Technology

MINUSTAH
: United Nations Stabilization Mission in Haiti

MIP
: Multilateral Interoperability Programme

SA
: Situational Awareness

SAGAT
: Situation Awareness Global Assessment Technique.

SAAI
: Intrusion Alerts Automatic System

UAV
: Unmanned Aerial Vehicle

UDOP
User Defined Operational Picture

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