

13th ICCRTS: C2 for Complex Endeavors

ELICIT and the Future C2:

Theoretical Foundations for the Analysis of ELICIT Experiments

Topic 7: Network-Centric Experimentation and Analysis

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Theoretical Foundations for the Analysis of ELICIT Experiments**

Abstract

ELICIT, a research and experimentation programme developed for the CCRP, is a game-based simulation that provides a network-centric environment for a small group or organization using one of two different C2 approaches: Hierarchy and Edge.

The group goal is to find the *Who*, *What*, *Where* and *When* of a terrorist attack. Information elements are delivered to the individuals and might be disseminated through the group through information sharing and collaboration process. This generates different behaviors and dynamics in the information, cognitive and social domains that are interesting to analyze when considering the adopted C2 approach.

This paper provides the theoretical foundations for the analysis of ELICIT experiments, using NCW tenets and theory and the C2 Conceptual Reference Models recently developed by ASD-NII/OFT (2006, Alberts and Hayes) and NATO SAS-050 Research Group (2006, NATO SAS-050) as a conceptual framework. A mapping between ELICIT and these reference models variables and metrics is presented regarding the relevant domains: Information (richness, reach, security and interactions), Cognitive and Social (individual and shared awareness and understanding and quality of interactions).

Since ELICIT does not fully cover the spectrum of C2 approaches and domains, assumptions for compliances and non-compliances with the models are also described.

Keywords: ELICIT, C2 Conceptual Reference Model, NEC.

Introduction

The new military challenges include *complex endeavors* (2007, Alberts and Hayes) require effective coordination and collaboration between non-military organizations, such as intelligence agencies, police or medical aid. Therefore, new challenges require the adoption of new Command and Control (C2) approaches, such as Network Centric Warfare (NCW) and *Power-to-the-Edge* principles (2003, Alberts and Hayes), the latter characterized by broad distribution of information, unconstrained patterns of interactions and dynamic allocation of decision rights.

This process of transformation affects several core aspects of Military Organizations. The very definition and understanding of C2 is being reviewed¹ and is the focus of ASD-NII/OFT (2006, Alberts and Hayes) and NATO Research Groups (2006, NATO SAS-050). As a result of this process, a C2 Conceptual Model was created by SAS-050, providing a conceptual reference for further research and experimentation of new C2 approaches.

Within this scope, the Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust (ELICIT) was created. ELICIT uses two different C2 approaches and explores their effects on the human-in-the-loop and its implications on information, cognitive and social domains. So far, ELICIT has been used in Portugal, Singapore and United States of America. The Portuguese experiments have been conducted in the Military Academy.

ELICIT: An innovative C2 Research and Experimentation Program

ELICIT was developed to investigate social and cognitive impacts of different C2 approaches and organizational structures. Within this context, some hypothesis related with information sharing, shared awareness, and knowledge on task performance are tested. It consists in a software environment for conducting human-in-the-loop

¹ A major discontinuity that will need to be addressed will be the definition of the words themselves (2006, Alberts and Hayes).

experiments focused on information, cognitive, and social domain phenomena when operating in two different organizational structures: Traditional Hierarchical and Edge Organizations (2007, Hayes).

ELICIT is an open platform, conceptualized, designed and developed by EBR Inc. and Parity Communications Inc. and was sponsored by the U.S. DoD (OASD/NII) Command and Control Research Program (CCRP). For detailed information regarding the ELICIT experimental platform please refer to Mary Ruddy's paper *ELICIT – The Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust* (2007, Mary Ruddy).

Rules of the Game

ELICIT Experimental Platform consists of a software application that networks seventeen (17) individuals (herein referred as **players**) and enables them to exchange information, in order to accomplish an operational goal: the determination of the *Who, What, Where* and *When* pieces of information that describe the occurrence of an attack.

Throughout the experiments, clues (**factoids**) are randomly delivered to the players. Each **factoid** is a logical statement which must be combined with other factoids in order to reach the operational goal. Factoids can be measured in terms of their relevance as follows:

- Key (K) and Expertise (E) factoids are required to determine the solution. These are 25% of the total number of factoids.
- Supportive (S) factoids provide supportive information to K and E factoids. These are 25% of the total number of factoids.
- Noise/Nonessential (N) factoids do not provide information related to the solution. These are 50% of the total number of factoids.

As an additional constraint, the exchange of information is solely possible through the use of the ELICIT software application, either by **posting** or **sharing** information, in the form of fixed text messages:

- **Posting a factoid** will publish it to a repository (web site) visible to the entire team;
- **Sharing a factoid** will publish it to a specific member.

This field experiment uses two different organizational structures:

- A traditional hierarchical command structure, where four teams of four players each are randomly created. Each team has its own leader and is assigned to determine one of the Ws (Who, What, Where and When). Each team member may only share factoids within his team and may post factoids in the team site, making it accessible to all team members. An overall team coordinator is randomly assigned, with the ability to conduct cross-team information exchange.
- An edge organizational structure, where all team players can share information with any other player. There are no upper/lower hierarchies or users with different privileges. Four thematic sites exist for Who, What, Where and When, where the players can post information.

Purpose

The possibility to use one of these structures is a core aspect of ELICIT, since its initial purpose was to validate the hypothesis that Edge organizations outperform Hierarchy organizations. However, in order to understand and to allow an appropriate validation of this hypothesis, observation and analysis of information dissemination, as well as an analysis of patterns of interactions characteristics and dynamics generated throughout the experiment is considerate of major importance. In order to conduct this analysis it was explored a perspective based on NCW tenets and theory and the C2 Conceptual Reference Models are presented next.

ELICIT and NCW: Making the Bridge

Being ELICIT a research program based on fundamental NCW concepts and tenets, it is assumed that the correlation and the possibility to apply the results derived from ELICIT Experiments to NCW should be further explored. This section presents the deduced mapping between ELICIT and NCW, in terms of its tenets and C2 Conceptual Model.

This mapping is analysed in terms of:

- The C2 Approach Space
- The C2 Domains
- The Metrics and Hypothesis

ELICIT and the C2 Approach Space

The following table summarises the mapping of the C2 Approach Space into the ELICIT organization structures:

ELICIT Organizational Structure	Hierarchy	Edge
C2 Key Factors		
Allocation of decision rights	<not covered>	<not covered>
Patterns of interaction	Tightly constrained (across teams) ² Unconstrained (within teams)	Unconstrained
Distribution of information	Tight control (across teams)	Broad dissemination (peer-to-peer allowed)

Table 1 - C2 Approach Space key factors and ELICIT Experiments

² Note that this is a *soft* constraint. This is a rule in Hierarchical organizational structure which is set by the instructions, but is not enforced by the ELICIT client software tool (version 1.0.0.61015).

The **allocation of decision rights** enables mechanisms for information sharing and collaboration, influencing the patterns of interaction at the social and information domains and has a clear impact on information distribution. This factor comprises the capacity, the information resources and the means to make effective decisions, such as resources allocation and assignment.

At ELICIT Experiments, there are no evidences of a decision-making process that empowers specific players to make a decision that effectively bounds the collective, making it a team's or a group's decision. The identifications of 4Ws by all players, during the experiments runs, are a mere collection of expressed individual understanding of the situation. Hence, combining the allocation of decision rights to ELICIT, it is possible to conclude that this C2 Approach Space key factor is not covered.

The determination of organizational roles enables different behaviors that create different **patterns of interaction**. Ultimately, it is the Human behavioral nature that may be considered the critical element in the tenets of Network-Enabled Operations (NEO) and the principles of *Power to The Edge* (2003, Alberts and Hayes). The richest pattern of interaction is the broadband/fully-connected system, which links everyone with full interoperability (technical, syntactical, semantic and social) in a cyber environment to support continuous collaboration. In this system, information is posted in such a way that it may be available in time to all that need it. On the other hand, the poorest pattern of interaction is the bidirectional dialogue of two actors (fully hierarchical), that involves a constrained interaction that may be determined by low bandwidth and poor interoperability.

ELICIT is able to create a fully distributed broadband system for the edge organization or to enforce interactions constraints (hierarchy) for the traditional hierarchical system.

With respect to **distribution of information**, emphasis is placed on the **quality of information position**, characterized by its four dimensions: **richness, reach, security** and **interaction**. ELICIT allows to extract metrics and data associated with variables related to the information distribution key factor, either with tight control (in hierarchy) or broad dissemination (in edge).

This evidence precludes the onus upon the physical enabler and amplifies the importance of analysing the importance of will and intent and its implications at both information, cognitive and social domains.

ELICIT and the C2 Domains

In order to solve the puzzle (find the *Who/What/Where/When*), the players must use the software in order to reach, share, analyse and understand the factoids. This involves operations in the Information, Cognitive and Social Domains.

ELICIT software application publishes factoids to players and allow those players to exchange their factoids either by posting or sharing. Although the action of sharing information lies at the Information Domain, the act of posting or sharing represents a peer-to-peer (share) or group (post) interaction. Therefore, it is considered that it has a purpose and represents a collaborative behaviour. Concluding, sharing or posting information in ELICIT occurs in the Cognitive and Social Domains with obvious implications at the Information Domain.

Furthermore, a key aspect in ELICIT lies at the Cognitive Domain, consisting in each player's awareness and understanding of the situation. Understanding can be measured when a player performs an identify action.

Derived from Figure 3, next figure depicts the mapping of ELICIT possible actions to the C2 Domains³.

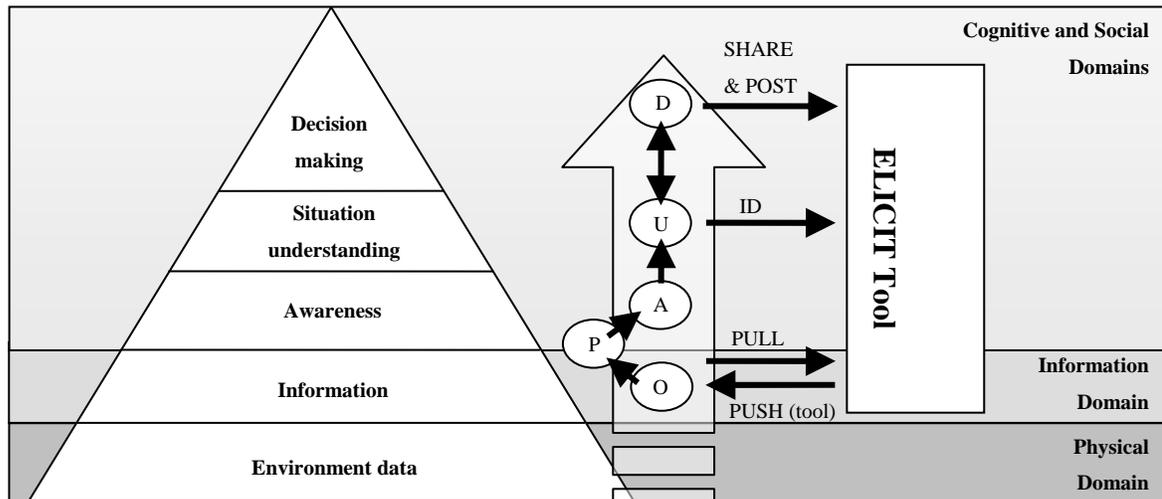


Figure 1 - ELICIT mapping to the C2 Domains

In order to clarify the mapping in Figure 1, the next Table presents its detailed description.

<i>C2 Domain</i>	<i>ELICIT Mapping Description</i>
Physical Domain	ELICIT does not cover the physical domain.
Information Domain	The following interactions occur: <ul style="list-style-type: none"> - PUSH: when the tool delivers information / factoids to a player - PULL: when the subject retrieves information from the tool Note that share and post actions also have impact in this Domain.
Cognitive Domain	Information is received and processed by the player (knowledge, perceptions, awareness and understanding). Understanding is measured when the subject performs an IDENTIFY.
Social Domain	POST and SHARE actions are considered social interactions in ELICIT. Furthermore: <ul style="list-style-type: none"> - POST is a weak form of interaction, since it is an indirect way of communication (through a web site). However, it is also the

³ A description of Figure 1 elements is presented in "The NCW C2 Primitives" annex section.

	<p>mean with the broadest range.</p> <ul style="list-style-type: none"> – SHARE is a strong form of interaction, since it is a direct communication to an individual. It is peer-to-peer.
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Table 2 - ELICIT mapping to C2 Domains

ELICIT Metrics

Related to the C2 Conceptual Model (2006, Alberts and Hayes and 2006, SAS-050), useful metrics and indicators can be retrieved from ELICIT experiments. The subsequent subsections present a set of variables observable in ELICIT relevant for analysis.

Information Domain (CCRP)

In the Information Domain, the following concept applies (2006, Alberts and Hayes):

- Quality of Information Position

The Quality of Information Position contains several variables, which are observable in ELICIT as follows:

- *Information Richness* is measured in terms of:
 - **Situation independent attributes:** since all factoids are correct, consistent and precise, all attributes (*correctness*, *consistency* and *precision*) have fixed value except *currency* which may be measured by calculating the time difference between *the current time* and the time when the factoid was first published.
 - **Situational context attributes:** *relevance* and *completeness* are measured using factoids metadata (namely the K,E and S values). *Timeliness* may be derived when all sufficient factoids to achieve the goal are present. *Confidence* may be obtained by analyzing the *willingness* to post and share factoids. *Accuracy* and *Trust* cannot be measured.

- Information Reach: all attributes are covered by ELICIT, namely *Accessibility Index (all and relevant)* and *Index of Shared Information (all and relevant)*. These are calculated by the percentage of K, E and S factoids accessible by a specific subject or by all.
- Information Security: none of its attributes (*Privacy, Integrity, Authenticity, Availability, Non-repudiation*) are not covered by ELICIT.
- Information Interactions: *Forms of information* are fixed (factoids contain fixed text) and *Nature of interaction* consists in push, share (equivalent to broadcast push) and pull.

Information Domain (SAS-050)

SAS-050 presents additional variables mapped in the Information Domain observable in ELICIT, namely:

- *Information Distribution* attributes such as *Information richness* (which differs semantically from the CCRP definition), derived by the quality of factoids published or shared, *Information transfer approach* obtained using Social Network Analysis. All other attributes are not observable in ELICIT or are equivalent to CCRP attributes presented in the respective subsection.
- *Information Quality* attributes, in which some are equivalent to the respective CCRP attributes or are not observable (*Source Characteristics, Service Characteristics, Sharability and Uncertainty*).
- *Collaboration* attributes, specifically *Collaboration capacity* (assessment of player's capability to adequately share information and interact with the other players), *Collaboration completeness* (determined by player collaboration in all *Ws*), *Collaboration participants* (assessment of all players behavior to share

information and interact with the other players), *Continuity of interactions* (analysis of players interactions in time (share/post) and reciprocal actions), *Frequency of interactions* (obtain shares/hour and posts/hour (per player and overall)) and *Interaction quality* (In conjunction with Information richness variable, analyze the capability to develop understanding).

- *Shared Information Quality* attributes are equivalent to the CCRP.

Information Assurance attributes (equivalent to CCRP Information Security) are not covered by ELICIT.

Information Domain (Extension to ELICIT)

Another interesting variables to analyze in ELICIT is “Information Reached”, that is, information that is accessible to a subject which is actually reached. For example, factoids posted in web-sites are accessible / reachable but unless a pull is performed the information is not reached⁴.

This concept doesn’t involve any cognitive processing of the information. This concept is only relevant due to the lack of the awareness metric in ELICIT (see *Quality of Sensemaking*).

The group metric “Shared Information Reached” also applies.

⁴ This is one disadvantage of the pull mechanism vs. the push mechanism for information dissemination: pull mechanisms rely on the consumer-side to retrieve information from the source, while push mechanisms deliver information to the consumer where notifications can be triggered (being the onus on the publisher side). One is smart-consumer (smart-pull) while the other is smart-publisher (smart-push). A mechanism not covered by ELICIT is the (smart) subscriber mechanism. This is a push-like mechanism (more efficient than pull) with onus on the consumer (to explicitly express interest in messages published by a publisher). It could be another method for information dissemination in ELICIT.

Cognitive and Social Domain (CCRP)

At the Cognitive and Social Domain, the following concepts applies:

- Quality of Sensemaking
- Quality of Interactions
- Quality of Command
- Quality of Control
- Quality of Execution

Quality of Command, Quality of Control and Quality of Execution are not covered by ELICIT.

The attributes of *Quality of Sensemaking* are (2006, Alberts and Hayes):

- *Quality of Individual Awareness*, not observable in ELICIT.
- *Quality of Individual Understanding*, retrieved when a player performs an identify allowing measuring *Correctness, Consistency, Currency, Completeness, Timeliness* and *Confidence*. *Precision, Relevance* and *Accuracy* are not observable.
- *Decisions* covered attributes are *Appropriateness* (relevant factoids shared/posted), *Completeness* (percentage of all shared/posted relevant factoids) and *Timeliness* (shared/ posted relevant factoids within *acceptable* time).
- *Quality of Shared Understanding* attributes being the union of the individual attribute variables, namely *Correctness, Consistency, Currency, Completeness* and *Confidence*. The *Precision, Relevance* and *Accuracy* variables aren't observable since the respective individual values also aren't observable.

Both *Agility* and *Quality of Shared Awareness* are not observable in ELICIT.

Note that, in ELICIT, it is not possible to (objectively) retrieve metrics regarding knowledge and awareness, either for individual or group. *Measuring awareness requires that the subjects' awareness of entities, relationships, patterns, and inferences all be recorded* (2006, Alberts and Hayes). The log data doesn't provide useful information regarding those aspects. An approach could be to analyze the subjects' scratch-papers and, from the notes, try to determine what the *individual perceives regarding the situation*.⁵

The attributes of *Quality of Interactions* (2006, Alberts and Hayes) observable in ELICIT are *Extent* (measured by determining the level of participation of the individuals), *Access* (determined by the organizational structure, namely no-cross team exchanges in Hierarchical or full and equal access to all participants in Edge), *Level of participation* (derived by measuring the number of pulls, posts and sharing intensity) and *Frequency* (derived by measuring the frequency of pulls, posts and sharing intensity). *Communications, Synchronicity, Richness* and *Scope* are not observable in ELICIT.

⁵ During the 4th July experiments at the Portuguese Academy, Dr. Richard Hayes (EBR Inc.) pointed out that by recording the subject action 'Add to my factoids' button in ELICIT could be a mechanism to determine his *awareness*. When a subject adds a factoid to 'My factoids' it means that he is *aware* of that factoid. However, the opposite is not true. Therefore, an instruction from *Command* (ELICIT subject instructions) could be: add to your 'My factoids' all factoids you consider relevant (and leave an option to remove them in case they are considered not relevant in the future). The factoid's attribute impact (K, E, S and N) could be used to determine some Awareness attributes, such as Consistency, Relevance and Completeness.

In this way, *Individual Awareness* could be measured (within an acceptable margin of error) throughout the experiment run, by keeping a track of the subject's 'My Factoids'. *Shared Awareness* could also be determined.

Cognitive and Social Domain (SAS-050)

SAS-050 defined the following main topics for the Cognitive and Social Domain:

- Individual Characteristics and Behaviors
- Individual Awareness, Understanding and Knowledge
- Team Characteristics
- Shared Awareness, Understanding and Knowledge

The attributes of *Individual Characteristics and Behaviors* observable in ELICIT are *Personality and Values* (Willingness to interact) are derived from *Quality of Interactions (individual)*, *Dynamic factors/State* (Trust) uses SNA, focusing on stronger interactions between players, *Response speed* (derived from time to react after a received factoid) and *Cooperative behavior* (derived from Quality of Interactions (individual)).

Individual Cognitive Abilities, Physical Abilities and *Quality of Plan* are not observable in ELICIT.

Individual Awareness, Understanding and Knowledge attribute *Quality of Understanding* is equivalent to the CCRP attribute.

Team Characteristics attribute *Hardness* may be observed conducting several ELICIT runs with the same players having the same identities. The analysis will determine if stronger relations between participants were development and what will be the impact in effectiveness and efficiency.

Shared Awareness, Understanding and Knowledge attribute *Quality of Shared Understanding* is equivalent to the CCRP attribute.

Task Performance attributes *Individual task efficiency, Individual task quality, Task competence, Task efficiency, Task speed* and *Task understanding* may be derived from

the variables *Quality of Understanding* (CCRP), *Collaboration* (SAS-050) and *Information Distribution* (SAS-050).

High-Level Measures of Merit (SAS-050)

The following variables were defined:

- *Force Effectiveness* determined when a team reaches a correct shared understanding. Note that, in Hierarchy, *Force Effectiveness* refers to the team result while in Edge it is equivalent to *Mission Effectiveness*.
- *Mission Effectiveness* determined when a team reaches a correct shared understanding.

Furthermore, the following variables are added:

- *Force Efficiency* determined by force effectiveness over time⁶.
- *Mission Efficiency* determined by *Mission Effectiveness* over time⁶.

Analysis over Time

A notable characteristic of ELICIT experiments is the possibility to extract metrics over time, with a high level of detail.

Adding the time domain to the analysis allows observation of the dynamics generated by the individuals' interactions and network cognitive convergence. Some examples are presented as follows:

⁶ Efficiency is understood as accomplishing the objectives with the appropriate use of resources (e.g. human, material, cost and time). For this work, time will be considered.

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- *Information Quality Position and Quality of Shared Information* (Is Information Quality and Shared Information Quality increasing over time?)
 - *Collaboration* (Is Collaboration increasing over time?)
 - *Shared Understanding* (Are the group identifies converging to a common solution? Is the group shared understanding converging to the right solution?).

Furthermore, analysis over time allows determining (inter)relations between variables and their effects. In next section, Table 19 illustrates the interrelation of observable and verifiable hypothesis in ELICIT, derived from the NCW tenets. Their interrelation might be validated when analyzing their variation across the time domain.

Hypothesis for verification

Considering the concepts and definitions presented herein, the NCW tenets and the C2 literature referred throughout this work (see Annex A), some hypothesis are derived, which may be observable in and verifiable by ELICIT experiments.

1. Robustly networking a group *increases* information sharing and collaboration;
2. Increased information sharing and collaboration *improves* information quality position;
3. Improved information quality position *improves* situation awareness and understanding;
4. Improved situation awareness and collaboration *improves* shared awareness and understanding;
5. Improved shared awareness and understanding *improves* mission effectiveness.

In order to enhance a better overview of the existing correlation between these hypotheses, next figure depicts a simplistic chain regarding the presented hypotheses:

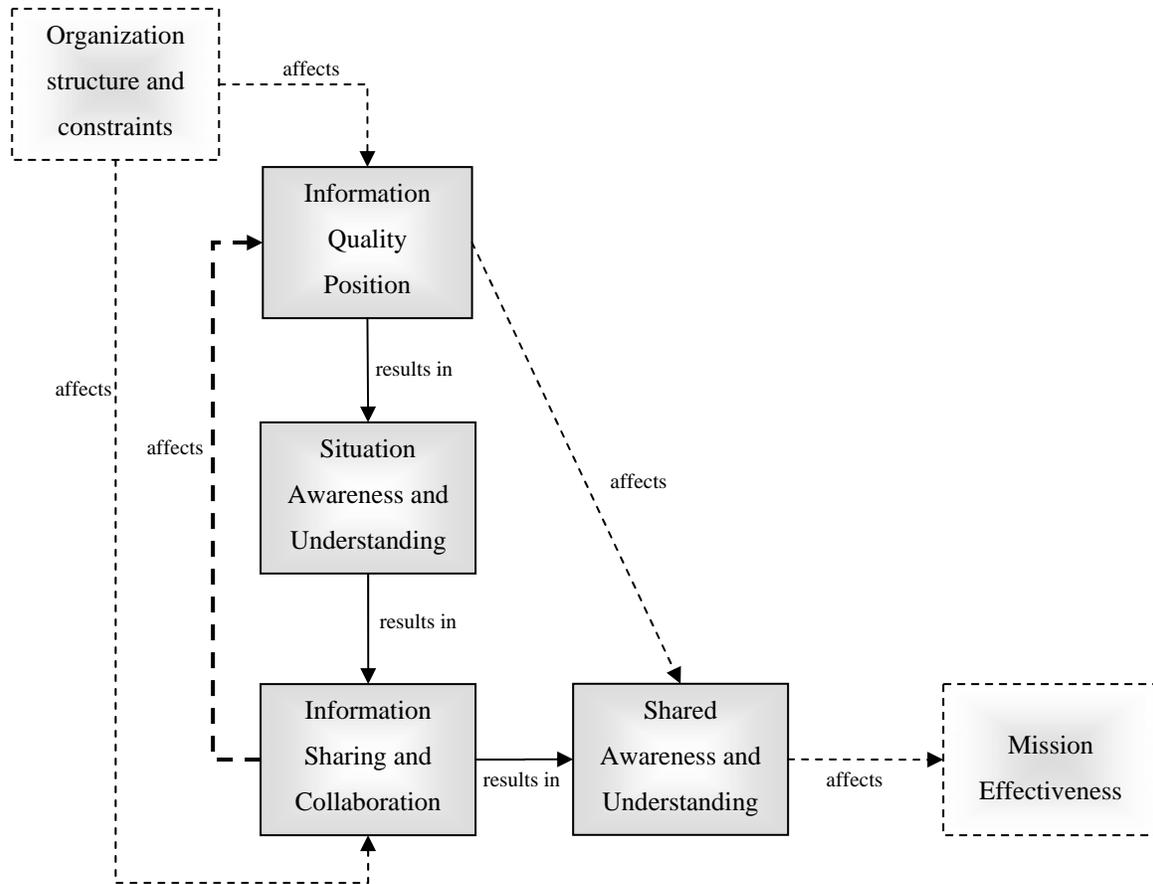


Table 3 – Existing interrelation of observable and verifiable hypothesis in ELICIT

Introducing the two different organizational structures, Edge vs Hierarchical, and their characteristics in the C2 approach space (see Table 16), the following additional hypothesis are derived.

6. Edge Organizations achieve *higher levels* of information quality position than Hierarchy Organizations.
7. Edge Organizations achieve *higher levels* of sharing information and collaboration than Hierarchy Organizations.
8. Edge Organizations achieve *higher levels* of shared awareness and understanding than Hierarchy Organizations.
9. Edge Organizations achieve *better* mission effectiveness than Hierarchy Organizations.

Furthermore, time analysis allows validating the following hypothesis:

1. Edge Organizations are *faster* to achieve a *high level* of information quality position than Hierarchy Organizations.
2. Edge Organizations are *faster* to achieve a *high level* of sharing information and collaboration than Hierarchy Organizations.
3. Edge Organizations are *faster* to achieve a *high level* of shared awareness and understanding than Hierarchy Organizations.
4. Edge Organizations are *more efficient*⁷ than Hierarchy Organizations.

The following variables, derived from the identified hypothesis, can be measured in ELICIT:

⁷ In ELICIT, more efficient is considered as accomplishing mission in less time.

- information quality position
- sharing information and collaboration⁸
- shared understanding
- mission effectiveness

The following variables cannot be measured in ELICIT:

- shared awareness

Further hypothesis to observe and analyze

(As described in ELICIT and the C2 Approach Space section of this paper, Edge and Hierarchical Organizations represent two different types of C2 Approaches. The comparison of their different characteristics (attribute values) reflects this evidence as presented in the next table (2003, Alberts and Hayes):

⁸ *Successful collaboration is the means by which Individual Information, Awareness, and Understanding are converted into Shared Information, Awareness, and Understanding* (2006, Alberts and Hayes). Therefore, in ELICIT, successful collaboration will be determined correlating the *Decision, Quality of Interactions* and *Shared Information and Understanding* variables. *Shared Awareness* cannot be measured in ELICIT.

	Hierarchies	Edge Organizations
Command	By directive	Establishing conditions
Leadership	By position	By competence
Control	By direction	An emergent property
Decisionmaking	Line function	Everyone's job
Information	Hoarded	Shared
Predominant Information Flows	Vertical, coupled with chain of command	Horizontal, independent of chain of command
Information Management	Push	Post - Pull
Sources of Information	Stovepipe monopolies	Eclectic, adaptable marketplaces
Organizational Processes	Prescribed Sequential	Dynamic Concurrent
Individuals at the Edge	Constrained	Empowered

Table 4 - Comparison of Attributes of Hierarchal and Edge Organizations

The following attributes will be observed and analyzed in ELICIT: *Information*, *Predominant Information Flows*, *Information Management* and *Individuals at the Edge*, represent important attributes and will require further observation and analysis, namely with the formulation of the following hypothesis:

- In Edge Organizations, *Information* is shared among the participants, *Predominant Information Flows* is horizontal and independent of the chain of command, *Information Management* is mostly post-pull and *Individuals at the Edge* are empowered.
- In Hierarchy Organizations, *Information* is hoarded among the participants, *Predominant Information Flows* is vertical and coupled with the chain of command, *Information Management* is mostly push and *Individuals at the Edge* are constrained.

The Way Ahead

ELICIT is not a C2 System.

ELICIT is a simple, small-scale experiment that is mainly about information sharing and cognitive activity. Furthermore, information sharing in ELICIT is highly constrained in terms of their form and nature of interactions.

Nevertheless, ELICIT provides a rich environment for analysis since it allows to:

- Extract a rich set of metrics (hard-data) that are present within the C2 CRM. ELICIT constraints in the form and nature of interactions allows using automated mechanisms to efficiently extract these metrics.
- Measure variables over the time domain, which allows determining the convergence of the system towards the desired end-state (correct and full level of shared understanding for mission accomplishment).
- Observe (inter)relations between variables and their effects, supported by the time domain.

Furthermore, current ELICIT constraints presents the following benefits:

- Allow detailed analysis of experiments (allows hard-data automatic extraction),
- Validate a basis set of hypothesis which will serve as basis for subsequent experimental modifications and extensions.
- Limit the number of metrics and variables to observe. Considering that the full C2 CRM is extensive and detailed, to analyse and validate subsets of the model is advisable.

Moreover, the two organization models (Hierarchy and Edge) represent two different C2 approaches which operate in a computer network-centric environment. Therefore, ELICIT becomes an interesting platform to analyze each of the approaches and to compare them in terms of their variable values and behaviors. In practice, to determine and compare their *value*. In this context, several hypothesis were raised for verification (or not) in ELICIT (see [2007, HAYES], [2007, HAYES, HAYES and MANSO] for presentation of ELICIT experiments metrics and analysis).

The vision presented in this paper, the theoretical foundations for analysing the ELICIT experiments, was defined as a basis to gain a deeper understanding of a subset of C2 concepts and definitions using an experimental approach. It uses as main references the C2 CRM developed by ASD-NII/OFT (2006, Alberts and Hayes) and NATO SAS-050 Research Group (2006, NATO SAS-050). Subsequent work will use these foundations to to extract the metrics, observe their relations and effects and validate the hypothesis.

Certainly, future extensions and adaptations to ELICIT, such as adding the *allocation of decision rights* dimension and enriching the forms of interaction, will contribute to an increase compliance with the C2 CRM. That is a work for the future.

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Annex A - ELICIT to NCW Domains Detailed Mapping

Information Domain (CCRP)

In the Information Domain, the following concept applies (2006, Alberts and Hayes):

- Quality of Information Position

The attributes of Quality of Information Position are:

- Information Richness
- Information Reach
- Information Security
- Information Interactions

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Information Richness (situation independent)	Correctness	Fixed Value. All factoids are consistent with ground truth.
	Consistency	Fixed Value. All factoids are internally consistent.
	Currency	Covered. Difference between the current time and the time when the factoid was first published.
	Precision	Not covered.
Information Richness (situational context.)	Relevance	Covered. Relevant information: K, E and S factoids. N are not relevant.
	Completeness	Covered. Percentage of K and E factoids attained by a subject. S are not included.

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	Accuracy	Not covered.
	Timeliness	Partially covered. Shall be analyzed the time when the required information to solve the puzzle is available.
	Trust	Not covered.
	Confidence	Covered. Shall be analyzed the willingness to post and share the factoids.
Information Reach	Accessibility Index (all)	Covered. Percentage of factoids accessible by a subject.
	Accessibility Index (relevant)	Covered. Percentage of K, E and S factoids accessible by a subject.
	Index of Shared Information (all)	Covered. Percentage of factoids accessible by all subjects (mean value).
	Index of Shared Information (relevant)	Covered. Percentage of K, E and S factoids accessible by all subjects (mean value).
Information Security	Privacy Integrity Authenticity Availability Non-repudiation	Not covered.
Information Interactions	Forms of information	Fixed Value. Restrictive in ELICIT: factoids are fixed text.
	Nature of interaction	Fixed Value. Restrictive in ELICIT: push, share, pull factoids (fixed text).

Information Domain (SAS-050)

The NATO SAS-050 group defined variables in the Information Domain (2006, SAS-050) are presented in the next table:

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Information Distribution	Communication systems characteristics	Not covered.
	Information richness (differs semantically from the CCRP definition)	Covered. Quality of information used by players is obtained by measuring the quality of factoids published or shared.
	Information transfer approach	Partially covered. SNA will be used to perform a soft-analysis.
	Network reach	Fixed Value. All players can share information.
	Network richness	Accessibility Index (relevant), part of Information Reach, will be used instead.
	Quality of visualization	<i>Accessibility Index (relevant)</i> , part of <i>Information Reach</i> , will be used.
Information Quality (only shown different attributes from CCRP)	Source Characteristics	Not covered.
	Service Characteristics	Not covered.
	Sharability	Fixed Value. All information is understandable by the nodes.
	Uncertainty	Not covered.

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<p>Information Assurance (Information Security in CCRP)</p>	<p>Confidentiality Information Pedigree Network Assurance Network Redundancy Network Reliability Network Sustainability</p>	<p>Not covered. Also Authenticity, Availability, Privacy, Integrity and Non-repudiation attributes, present in Information Security, are included.</p>
<p>Collaboration</p>	<p>Collaboration capacity</p>	<p>Partially covered. Assessment of player's capability to adequately share information and interact with the other players. SNA will complement this analysis.</p>
	<p>Collaboration completeness</p>	<p>Partially covered. Did the player collaborated in all Ws?</p>
	<p>Collaboration mechanism</p>	<p>Fixed Value. ELICIT by default enables collaboration in a restricted form.</p>
	<p>Collaboration participants</p>	<p>Partially covered. Assessment of all players behavior to share information and interact with the other players. SNA will complement this analysis.</p>
	<p>Continuity of interactions</p>	<p>Covered. Analysis of players interactions in time (share/post) and reciprocal actions.</p>
	<p>Frequency of interactions</p>	<p>Covered. Obtain shares/hour and posts/hour (per player and overall).</p>

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	Interaction quality	Partially covered. In conjunction with <i>Information richness</i> variable, analyze the capability to develop understanding (being awareness not measured in ELICIT).
Shared Quality	Completeness Currency Relevance Timeliness	Covered. Shared Information is a subset of the information available. It includes only the information with is shared among the team.
	Accuracy Consistency Correctness Precision Uncertainty	Not covered.

Table 5 -SAS-050 Measurements in the Information Domain (Quality of Information Position)

Information Domain (Extension to ELICIT)

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Information Reached	Reached Index (all)	Covered. Percentage of factoids reached by a subject.
	Reached Index (relevant)	Covered. Percentage of K, E and S factoids reached by a subject.
	Index of Shared Information Reached (all)	Covered. Percentage of factoids reached by all subjects (mean value).

	Index of Shared Information Reached (relevant)	Covered. Percentage of K, E and S factoids reached by all subjects (mean value).
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Table 6 - ELICIT Measurements in the Information Domain (Quality of Information Position: Information Reached)

Cognitive and Social Domain (CCRP)

At the Cognitive and Social Domain, the following concept applies:

- Quality of Sensemaking
- Quality of Interactions
- Quality of Command
- Quality of Control
- Quality of Execution

Quality of Command, Quality of Control and Quality of Execution are not covered by ELICIT.

The attributes of Quality of Sensemaking are (2006, Alberts and Hayes):

- Quality of Individual Awareness and Understanding
- Decisions
- Agility
- Quality of Shared Awareness and Understanding

Note that, in ELICIT, it is not possible to (objectively) retrieve metrics regarding knowledge and awareness, either for individual or group. *Measuring awareness requires that the subjects' awareness of entities, relationships, patterns, and inferences all be recorded* (2006, Alberts and Hayes). The log data doesn't provide useful information

regarding those aspects. An approach could be to analyze the subjects' scratch-papers and, from the notes, try to determine what the *individual perceives regarding the situation*.⁹

Passar tabela seguinte para Anexo e criar um para de ligação com o Anexo e com o ponto anterior.

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Quality of Individual Awareness	<not covered>	Not covered. Awareness is what an individual perceives regarding the situation. It is not being retrieved by ELICIT.
Quality of Individual Understanding (situation independent)	Correctness	Fully covered. Determined using the recorded subject's identify.
	Consistency	Fully covered. Comparison between current and previous subject's identify.
	Currency	Partially covered. Considered the time to identify.

⁹ During the 4th July experiments at the Portuguese Academy, Dr. Hayes pointed out that by recording the subject action 'Add to my factoids' button in ELICIT could be a mechanism to determine his *awareness*. When a subject adds a factoid to 'My factoids' it means that he is *aware* of that factoid. However, the opposite is not true. Therefore, an instruction from *Command* (ELICIT subject instructions) could be: add to your 'My factoids' all factoids you consider relevant (and leave an option to remove them in case they are considered not relevant in the future). The factoid's attribute impact (K, E, S and N) could be used to determine some Awareness attributes, such as Consistency, Relevance and Completeness. In this way, *Individual Awareness* could be measured (within an acceptable margin of error) throughout the experiment run, by keeping a track of the subject's 'My Factoids'. *Shared Awareness* could also be determined.

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	Precision	Not covered.
Quality of Individual Understanding (situation dependent)	Relevance	Not covered. Use correctness instead.
	Completeness	Fully covered. Determined using the recorded subject's identify.
	Accuracy	Not covered. Use precision instead.
	Timeliness	Fully covered. Successful if solved before the end of trial.
	Confidence	Partially covered. Confidence may be deducted from the player's quality of interactions and quality of information shared.
Decisions (situation independent)	Consistency Currency Precision	Not covered.
Decisions (situation dependent)	Appropriateness Completeness (Depth, Breadth and Time) Accuracy Timeliness Confidence	Partially covered. The following will be mapped: – <i>Appropriateness</i> – where the factoids shared/posted relevant? – <i>Completeness</i> – shared/posted all relevant factoids? – <i>Timeliness</i> - shared/ posted relevant factoids within <i>acceptable</i> time?
Agility	<not covered>	Not covered.
Quality of Shared Awareness	<not covered>	Not covered.

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Quality of Shared Understanding (situation independent)	Extent	Fully covered.
	Correctness	Fully covered.
	Consistency	Fully covered.
	Currency	Partially covered. Considered the overall time to identify.
	Precision	Not covered.
Quality of Shared Understanding (situation dependent)	Relevance	Not covered.
	Completeness	Fully covered.
	Accuracy	Not covered.
	Confidence	Partially covered. (see individual attribute)

Table 7 – ELICIT Measurements in the Cognitive and Social Domains (Quality of Sensemaking)

The attributes of Quality of Interactions and respective ELICIT coverage is presented in the next table.

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Quality of Interactions	Extent	Partially Covered. Aspects to observe: <ul style="list-style-type: none"> – Are all participants involved? (do they share/post/pull) – Does collaboration cuts across organizational boundaries?

	Access	Fully Covered. <ul style="list-style-type: none"> – In Hierarchical, access outside teams is not allowed for non-coordinators (limited access to most participants). – In Edge, full and equal access to all participants.
	Communications	Not covered. ELICIT operates in a LAN (with full bandwidth).
	Level of participation	Partially Covered. Aspects to observe: <ul style="list-style-type: none"> – Subjects more/less active in pulling, posting and sharing
	Frequency	Partially Covered. Aspects to observe: <ul style="list-style-type: none"> – Subjects more/less active in pulling, posting and sharing
	Synchronicity	Not covered. ELICIT communications are always asynchronous.
	Richness	Not covered. ELICIT communications involve only fixed-text.
	Scope	Not covered. ELICIT communications involve only the exchange of fixed-text.

Table 8 - ELICIT Measurements in the Cognitive and Social Domains (Quality of Interactions)

Cognitive and Social Domain (SAS-050)

SAS-050 defined the following main topics for the Cognitive and Social Domain:

- Individual Characteristics and Behaviors
- Individual Awareness, Understanding and Knowledge
- Team Characteristics

-
- Shared Awareness, Understanding and Knowledge

The variables relevant for analysis in ELICIT are presented in the next table.

Passar tabela seguinte para Anexo e criar um para de ligação com o Anexo e com o ponto anterior.

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Individual Characteristics	Individual Cognitive Abilities	Not covered.
	Personality and Values: – Willingness to interact	Partially Covered: – Derived from <i>Quality of Interactions (individual)</i> .
	Physical Abilities	Not covered.
	Dynamic factors/State: – Trust	Partially Covered: – SNA, with focus on stronger interactions between players.
	Quality of Plan	Not covered.
Behaviors	Response speed Cooperative behavior	Partially Covered: – <i>Response speed</i> will be derived from time to react after a received factoid. <i>Cooperative behavior</i> will be derived from <i>Quality of Interactions (individual)</i> .
Individual Awareness, Understanding and Knowledge	Quality of Understanding	Same as <i>Quality of Understanding (CCRP)</i> .

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Team Characteristics	Hardness	Partially Covered: <i>Hardness</i> may be explored using the same players with the same identity in several ELICIT runs. Analyze development of stronger relations between participants.
Shared Awareness, Understanding and Knowledge	Quality of Shared Understanding	Same as <i>Quality of Shared Understanding</i> (CCRP).
Task Performance	Individual task efficiency Individual task quality Task competence Task efficiency Task speed Task understanding	Partially covered: Measures regarding <i>Quality of Understanding</i> (CCRP), <i>Collaboration</i> (SAS-050) and <i>Information Distribution</i> (SAS-050) will provide indicators for assessing Task Performance.

Table 9 - ELICIT Measurements in the Cognitive and Social Domains (SAS-050)

High-Level Measures of Merit (SAS-050)

<i>Variable</i>	<i>Attributes</i>	<i>ELICIT Coverage</i>
Force Effectiveness	Force Effectiveness	Fully covered: <ul style="list-style-type: none"> - Determined when team reach a correct shared understanding. - Efficiency will also be measured (correct shared understanding in the smaller amount of time) In Hierarchy, <i>Force Effectiveness</i> refers to the team result. In Edge, it is equivalent to <i>Mission Effectiveness</i> .
Mission Effectiveness	Mission Effectiveness	Fully covered: <ul style="list-style-type: none"> - Determined when team reach a correct shared understanding. - Efficiency will also be measured (correct shared understanding in the smaller amount of time)

Table 10 - ELICIT Measurements in the High-Level Measures of Merit (SAS-050)

Annex X - Network Centric Warfare: Concepts and Definitions

The concepts and definitions related with Network Centric Warfare are first introduced by explaining the NCW Tenets, followed by the NCW C2 Domains, the NCW primitives and the C2 Conceptual Model. Finally, Classic C2 and Edge Organizations characteristics are briefly introduced.

The NCW Tenets

Alberts *et al* introduced the tenets of Network Centric Warfare (1999, Alberts *et al*) as follows:

1. A robustly networked force improves information sharing.
2. Information sharing and collaboration enhance the quality of information and shared situational awareness.
3. Shared situational awareness enables self-synchronization.
4. These, in turn, dramatically increase mission effectiveness.

These tenets have been revisited and, eight years latter, Alberts and Hayes (2007, Alberts and Hayes) applied them to the context of a network centric enterprise (which is wider than force)¹⁰:

1. Robustly networking an enterprise leads to widespread information sharing and collaboration.
2. Increased sharing and collaboration improve both individual and shared awareness.
3. Shared awareness and collaboration improve decisions and, in the presence of edge approaches to command and control, enable self-synchronization.

¹⁰ Other terms, such as organization, are also used.

4. The result is dramatic improvement in mission/enterprise effectiveness and agility.

The revised tenets augment the aspects of interaction in step 1 (networking, sharing and collaboration). Networking forces are the basis of this theoretical foundation (where the human is the central point¹¹), which evolve to shared awareness and self-synchronization. When in C2 edge approach, this will then to improve decisions, resulting in an increase in effectiveness and agility.

In Military Organizations, *Command and Control*¹² is about focusing the efforts of a number of entities (individuals and organizations) and resources, including information, toward the achievement of some task, objective, or goal (2006, Alberts and Hayes). Moreover, the following functions were associated to C2:

- Establishing intent (the goal or objective)
- Determining roles, responsibilities, and relationships
- Establishing rules and constraints (schedules, etc.)
- Monitoring and assessing the situation and progress
- Leadership: inspiring, motivating, and engendering trust¹³
- Training and education
- Provisioning

The NCW C2 Domains

The fundamental capabilities of a network-centric enterprise are characterized in four domains (2003 and 2007, Alberts and Hayes):

¹¹ Therefore the use of networking instead of network

¹² Being *management* its counterpart in the civil domain

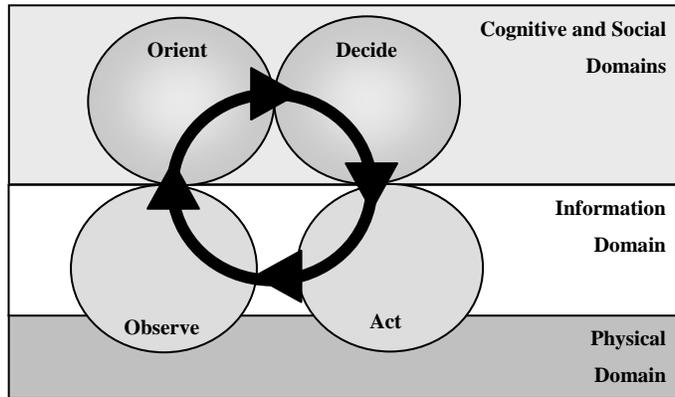
¹³ Functions, normally associated with leadership, determine the
(1) extent to which individual participants are willing to contribute and
(2) the nature of the interactions that take place.

These are crucial aspects when operating in NCW.

- **Physical Domain:** All enterprise entities are robustly networked, achieving secure and seamless connectivity and interoperability. It may be composed of sensors, systems, platforms, and facilities.
- **Information Domain:** All participants have the capability to share, access, display, store, process and protect information, not only within their organizations but with other enterprise entities as appropriate. Participants are able to collaborate in the information domain and individually or collectively conduct information operations.
- **Cognitive Domain:** Each participant has the capability to develop high quality awareness. This includes the perceptions and understanding of what the information states and means.
- **Social Domain:** The enterprise has the capability to develop shared awareness and understanding, including an understanding of command intent. The participants are capable of self-synchronization. It includes C2 processes and the interactions between and among individuals and entities that fundamentally define organization and doctrine.

The next figure presents, in a rather simplistic form, the mapping between the four domains and the traditional OODA loop¹⁴.

¹⁴ Alberts *et al*, in *Understanding Information Age* (2001), present the OODA loop view into the larger context of joint operations.



NOTE: Based on (2001, Alberts *et al*). The Social Domain was added to the original figure.

Figure 2 - Traditional View of C2: OODA Loop

The NCW C2 Primitives

The four domains reflect a cyclic transformation process. An alternative view, based on the Cognitive Pyramid presented in the SAS-050 Final Report (2006, NATO SAS-050) and adapted within the current context, is presented in the next figure.

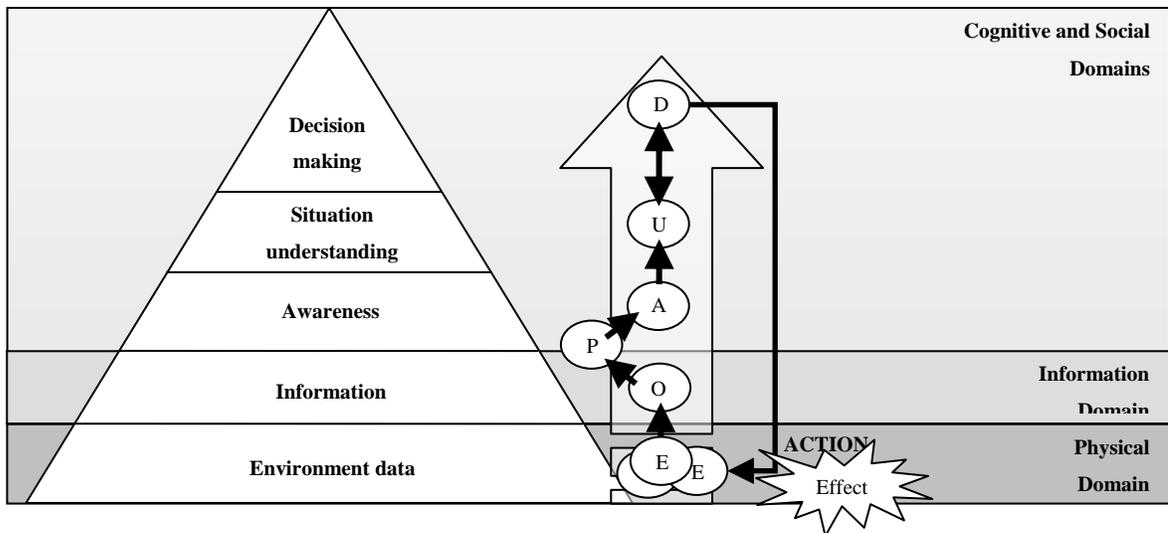


Figure 3 - NCW Cognitive Pyramid

The following table presents some of the primitives related to the theory of *how information affects the performance of individuals and organizations* (2001, Alberts *et al*). These are explicitly or implicitly present in the Cognitive Pyramid.

<i>Primitive</i>	<i>Description</i>
Observations/Events (data)	Representation of individual facts, concepts, or instructions in a manner suitable for communication, interpretation, or processing by humans or by automatic means.
Sensing	There are two modes: <ul style="list-style-type: none"> – Direct: when humans experience an object or event in the physical domain with one of their senses (such as seeing, hearing, or smelling), and the sensing registers directly in the cognitive domain (not displayed in the figure). – Indirect: when a sensor of some type is employed by a human to facilitate sensing some aspect of the physical domain.
Information	Result of putting individual observations (sensor returns or data items) into some meaningful context.
Knowledge	Involves conclusions drawn from patterns suggested by available information.
Awareness	Awareness relates to a situation and, as such, is the result of a complex interaction between prior knowledge (and beliefs) and current perceptions of reality. It focuses on what is known about past and present situations

Understanding	Understanding involves having a sufficient level of knowledge to be able to draw inferences about the possible consequences of the situation, as well as sufficient awareness of the situation to predict future patterns.
Decisions	Choices about what is to be done. They are acted upon and/or conveyed via the information domain for others to act upon, resulting in or influencing actions in the physical domain and/or other decisions.
Actions	Actions take place in the physical domain. They are triggered by decisions in the cognitive domain.

Table 11 - Primitives for evaluating the information impact on performance

In a networking environment, multiple actors interact and collaborate. Therefore, additional primitives are necessary (2001, Alberts *et al*). These are illustrated in the following figure.

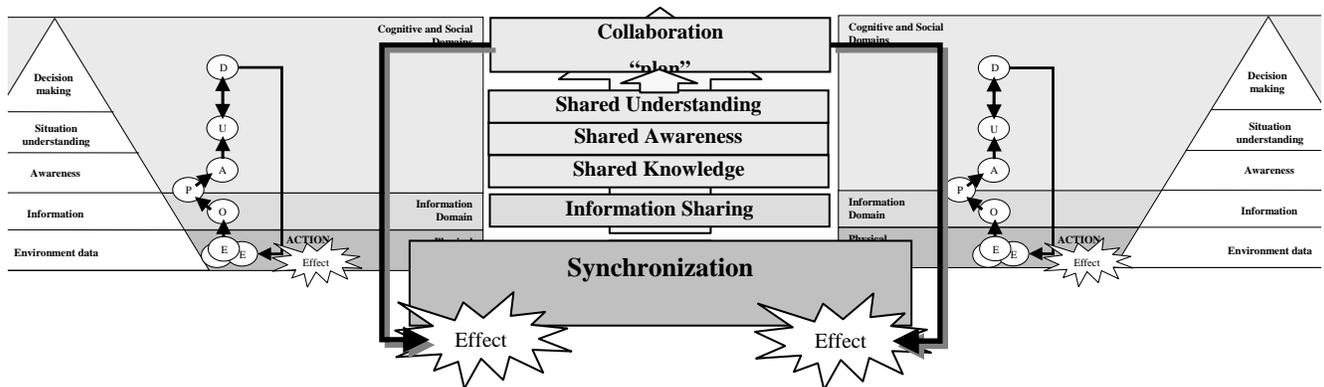


Table 12 - Primitives for evaluating the information impact on performance (collective)

The following table describes the primitives related to networking.

<i>Primitive</i>	<i>Description</i>
Information Sharing	Interaction that can take place between two or more entities in the information domain. These could be between humans, databases, or programs such as planning or fire control applications.
Shared Knowledge	Training and doctrine have been employed to develop a high degree of shared knowledge among troops so that they will understand and react to situations in a predictable way.
Shared Awareness	Exists when two or more entities are able to develop a similar awareness of a situation.
Shared Understanding	Exists when two or more entities are able to develop a similar understanding of a situation.
Collaboration	Process that takes place between two or more entities. Collaboration always implies working together toward a common purpose. This distinguishes it from simply sharing data, information, knowledge, or awareness.
Synchronization	Synchronization takes place in the physical domain (reality). Synchronization is the meaningful arrangement of things or effects in time and space.

Table 13 - Primitives for evaluating the information impact on performance (2)

The C2 Conceptual Model

The C2 Conceptual Model was developed to provide the conceptual foundation for the C2 research and experimentation necessary to develop and explore the new C2 Approaches needed for the Information Age transformation in the Armed Forces (2006, Alberts and Hayes).

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Two recent efforts took different developmental approaches: the first, a joint ASD-NII/OFT effort (2006, Alberts and Hayes), took a top-down approach based on the tenets of NCW and the second, a NATO RTO effort (2006, NATO SAS-050), took a bottom-up approach.

An overview of both models is presented in the next figure.

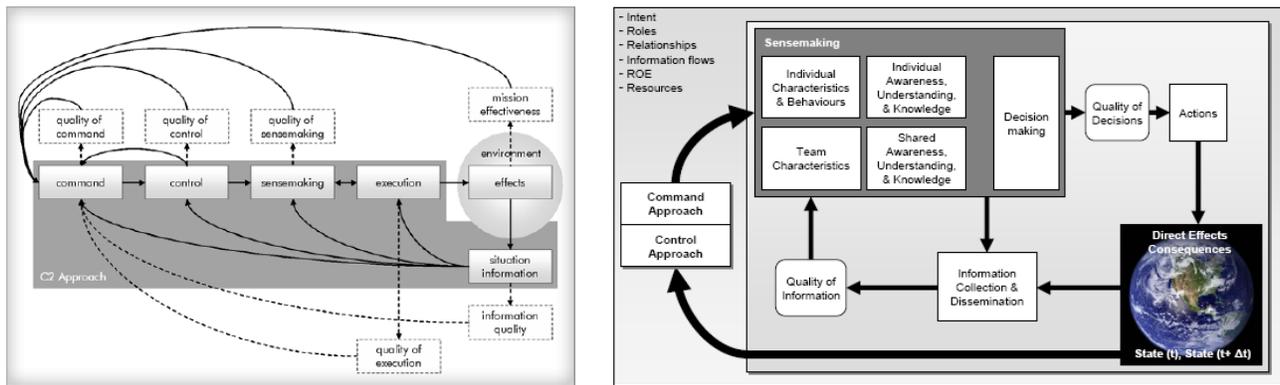


Table 14 – The C2 Conceptual Model: ASD-NII/OFT (left) and NATO SAS-050 (right)

For both models, a Value View was also developed, providing information regarding the quality and utility of a C2 Approach.

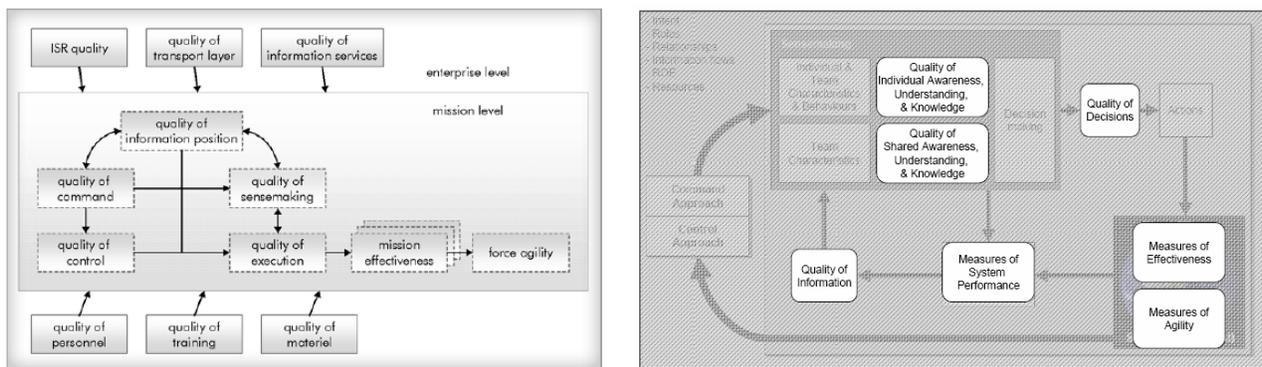


Table 15 – The C2 Conceptual Model: ASD-NII/OFT (left) and NATO SAS-050 (right)

The Value View provides interesting metrics for analysis regarding the scope of this work. These are described further in this document.

The C2 Approach Space: Classic C2 vs. Edge Organizations

In the process of defining the C2 Conceptual Model, the NATO SAS-050 Group adopted three main axis for defining the C2 Approach Space (2006, NATO SAS-050) consisting of:

- the way decision rights are allocated,
- the patterns of interaction that are enabled, and
- the distribution of information across the elements of the force.

The next figure presents the C2 approach space in a multidimensional view.

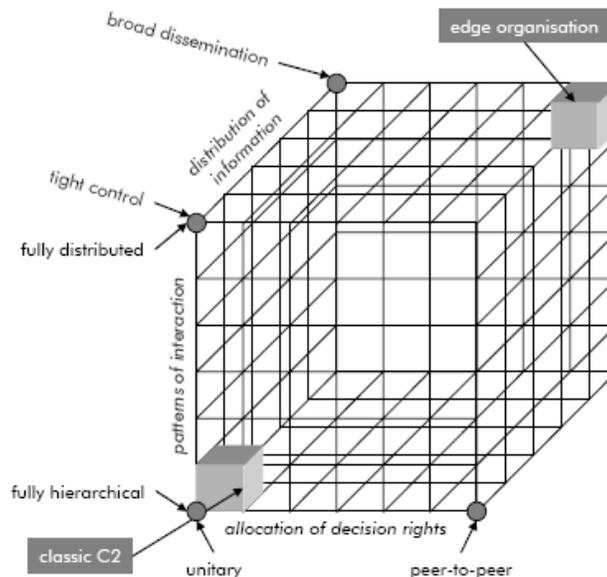


Figure 4 – The C2 Approach Space (2006, NATO SAS-050)

Two conceptual types of organizations, each positioned at opposite locations, are defined: *Classic C2* and *Edge Organization*. Their characterization in terms of their C2 approach is presented in the next table.

<i>C2 Approach Space</i>	<i>Classic C2</i>	<i>Edge organization</i>
Allocation of Decision Rights	Unitary	Peer-to-peer
Patterns of Interactions	Tightly constrained	Unconstrained
Distribution of Information	Tight control	Broad dissemination

Table 16 – C2 Approach Space for Classic C2 and Edge organizations

Robustly networking a force demands unconstrained *patterns of interaction* and broad dissemination of *distribution of information*, in order to rapidly share information and achieve high levels of shared awareness, which, in conjunction with distributed *allocation of decision rights*, may lead to collaboration, shared understanding and self-synchronization. *Edge Organizations* push these three key factors to the limit.

On the other hand, *Classic C2 Organizations* are industrial age stove-piped organizations, which tightly constrain the *patterns of interactions*, tightly control the *distribution of information* and centralize the *allocation of decision rights*. *Classic C2 Organizations* therefore don't promote wide information sharing or collaboration and are unlikely to achieve high degrees of shared awareness and understanding.

Therefore, selecting a C2 Approach will impact the NCW C2 Primitives (described in section 0) and, ultimately, the mission effectiveness.

However, *it is unlikely that one C2 Approach will be dominant over the full range of missions and circumstances and that it is likely that different C2 Approaches would be*

*appropriate for different organizations, functions, or at different points in time during the same operation*¹⁵. This would require a dynamic ability to coevolve (2006, Alberts and Hayes). It is also perceived that *choices made on these three fundamental dimensions are profound decisions with far-reaching implications for the overall C2 process* (2003, Alberts and Hayes).

¹⁵ In *Power to the Edge* (2003, Alberts and Hayes), six different approaches are identified (from most to least decentralized): *Cyclic, Interventionist, Problem-Solving, Problem-Bounding, Selective Control and Control Free*.

Annex X – CCRP Available Metrics

CCRP provided some metrics derived from five ELICIT experiments in the CCRP website (<http://www.dodccrp.org/html4/elicit.html>). These metrics account, for example, for posted clues, solved game references, activity and reciprocation rates and percentage of posted factoids, as presented next.

- **Solved Game (Mission Effectiveness and Efficiency):**
 - Yes/no (per *W*);
 - Could solve (indicates if a player had enough information available to achieve the solution)

Name	Team	Who	What	Where	Month	Day	Hour	AM/PM
Alex	C-C	X	W	X	W	X	X	X
Chris	Who	X	X	C	X	X	b	b
Dale	Who	X	W	W	X	X	W	W
Francis	Who	X	W	X	X	X	W	W
Harlan	Who	X	W	W	X	X	W	W
Jesse	What	X	W	X	b	b	b	X
Kim	What	X	W	X	W	W	W	X
Leslie	What	W	W	X	W	W	W	W
Morgan	What	X	W	X	W	W	W	X
Pat	Where	W	W	X	W	b	b	b
Quinn	Where	W	X	X	b	b	b	b
Robin	Where	W	W	W	b	b	b	b
Sam	Where	W	W	W	W	W	W	X
Sidney	When	X	W	W	W	X	X	X
Taylor	When	X	C	X	W	X	X	X
Val	When	X	W	X	b	X	X	X
Whitley	When	W	C	X	W	X	X	X

Table 17 - Individual identification matrix (Hierarchy)

- **Information Sharing**
 - Individual metrics:
 - Number of factoids shared (total);
 - Number of factoids received (total);
 - Number of reciprocated shares (total and within 5 minutes).

	23-Jun-06			
	shares rcv	shares	reciprocated	within 5 min.
Alex	38	0	0	0
Chris	35	3	1	0
Dale	30	9	2	2
Francois	31	13	3	2
Harlan	30	10	4	2
Jesse	10	64	2	1
Kim	6	80	4	1
Leslie	17	0	0	0
Morgan	6	70	0	0
Pat	22	0	0	0
Quinn	16	0	0	0
Robin	19	44	9	4
Sam	18	19	3	2
Sidney	21	20	5	2
Taylor	18	11	0	0
Val	20	12	1	0
Whitley	21	3	0	0

Table 18 - Activity and reciprocation rate (individual)

– Group metrics:

- Number of factoids posted (total and per time interval);
- Number of factoids shared (total and per time interval);
- Number of pulls (total and per time interval);
- Number of identifies (total and per time interval).

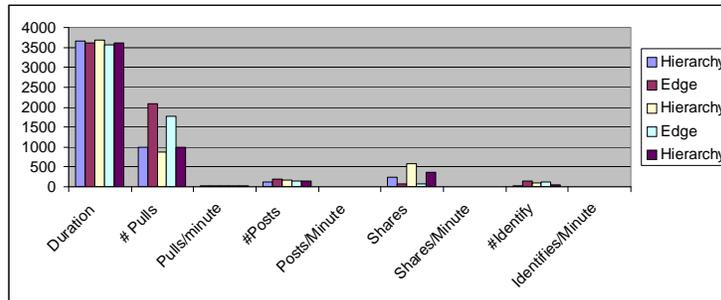


Figure 5 - Activity and reciprocation rate (group)