

13th ICCRTS: C2 for Complex Endeavors

Title: New Software Platform Capabilities and Experimentation Campaign for ELICIT

Topics:

- Organizational Issues (Edge organization vs. C2 vs. hybrid forms)
- Network-Centric Experimentation and Applications (Enhanced software platform for running experiments)
- Collaborative Technologies for Network-Centric Operations

Authors: Mary Ruddy and Mark Nissen

Point of Contact: Mary Ruddy

Name of Organization: Parity Communications, Inc. under contract to the Naval Post Graduate School Center for Edge Power

Complete Address: 22 Bartlett Avenue, Arlington, MA 02476

Telephone: 617-290-8591

E-mail Address: mary@parityinc.net

Title of Paper

New Software Platform Capabilities and Experimentation Campaign for ELICIT

Abstract

ELICIT is the Experimental Laboratory for Investigating Information-sharing Collaboration and Trust. A project of the Command and Control Research Program (CCRP) within the Office of the Assistant Secretary of Defense (NII), the ELICIT project developed an online multi-user software platform for conducting experiments in information-sharing and trust. The initial version of the software allowed researchers to model and experiment with a limited set of Command and Control (C2) organizations, processes and approaches in a computer-instrumented environment. The ELICIT software has since been enhanced to allow organization type to be configurable, thereby allowing researchers to experiment with a wider variety of C2 organizations, processes and approaches. In addition, the software has been further enhanced to support software agents as well as human participants, greatly expanding the avenues for research. Although the introduction and use of ELICIT remain relatively recent events, considerable research has been conducted already using this experimentation platform, and the C2 Research Community is gaining commensurate experience and insight into sound research design. Building upon such research and experience, we develop a multidimensional campaign for continued experimentation using the ELICIT platform. The campaign is populated with recent studies and guides future researchers toward high-payoff research areas that can be addressed using ELICIT.

Unclassified

Keywords: ELICIT, experimentation, edge organization, collaboration

Table of Contents

ELICIT Overview	3
Background.....	3
Experiment.....	3
Growing Research Community.....	4
New Configurable Organizations Capability	4
Motivation For Enhancement	4
Enhancement Capabilities.....	5
New Avenues For Experimentation Supported By Enhancement.....	6
New Agent-based Processing Capability	7
Motivation For Enhancement	7
Enhancement Capabilities.....	7
New Avenues For Experimentation Supported By Enhancement.....	7
Experimentation Campaign	8
Multidimensional Framework.....	9
Campaign Space Visualization	10
Example Population with Recent Studies.....	11
Self-Organization and Self-Synchronization	12
Conclusion and Suggestions for Future Research	13
References.....	14
Appendix A - ELICIT Configurable Organization Capability Details.....	16
Appendix B - ELICIT Agent-based Processing Capability Details.....	19
Appendix C – Experimentation Campaign Details.....	22

ELICIT Overview

Background

As part of its network centric warfare initiative, the Command and Control Research Program (CCRP) is engaged in developing and testing principles of organization that significantly transform traditional command and control practices that are hierarchical in nature and transfer power and decision rights to the edge of the organization. In their book, Power to the Edge, (2003) Alberts and Hayes argue that missions designed with superior shared awareness, trust and self-synchronization will perform with greater speed, precision, effectiveness, and agility than missions conducted under traditional hierarchical command structures.

The need for agility in information Age militaries is becoming increasingly important. As discussed in Understanding Command and Control by Alberts and Hayes (2006), in an era of complex coalition civil-military operations understanding how to organize for agility not just within a specific organization but also across differing organizations and cultures is key.

Historically there has been a shortage of formal experiment data on the efficacy of Edge vs. traditional organizational styles. Information on the applicability or desirability of one organizational style vs. another has been anecdotal. A typical battle or war game scenario has too many uncontrolled variables to produce any formal experiment data. In order to enable and foster the conduct of formal experiments in the principles of organization, the CCRP created an ongoing research Project called ELICIT: the Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust. As part of this program, the CCRP (Command and Control Research Program www.dodccrp.org) sponsored the development of a java-based software platform that can be used to run multi-user experiments in information sharing to empirically explore the relationships among approaches to command and control and organization, team and individual characteristics, as well as value-related measures that constitute the network-centric value chain. The network-centric value chain includes a robustly networked entity, information and collaboration behaviors, the quality of information and awareness, shared awareness, synchronization, and effectiveness.

The CCRP has facilitated the formation of a global COI (community of interest) to accelerate the development of a better understanding of network-centric concepts, approaches, and capabilities as well as power to the edge principles by building upon each others work, collaborating on campaigns of experimentation, and developing a shared body of knowledge. This paper is part of that ongoing effort.

Experiment

The ELICIT software platform currently uses a scenario that focuses on the task of discovering the “who”, “what”, “when”, and “where” of a future terrorist attack.

Information is provided to each of the participants when the session begins and at two other times during an experiment trial. The participants receive instructions about the nature of their organization and the information sharing modalities available to them. These constitute an experimental treatment and can be varied considerably to “create” a particular approach to command and control and organization. The participants can be selected from one organization, one type of organization or from many organizations with any mix of individual and team characteristics. The software enables numerous factors to be independently varied. Transaction logs and surveys or interviews associated with each experiment trial collect data that can be used to measure information sharing and collaboration behaviors as well as a variety of value metrics including the ability of individuals and teams to correctly identify the “who”, “what”, “when”, and “where” of a future terrorist attack and the time required to do so.

Growing Research Community

An ELICIT community of interest (COI) has members from several countries, including Canada, Germany, Portugal, Singapore, UK and the US, who are actively engaged in experimentation and analysis as well as the development of additional tools to support this research. Both civilian and military institutions are involved.

Experimentation, research and analysis have been ongoing. Some efforts have already resulted in research papers that have been posted on the ELICIT website. At the 12th International Command and Control Research and Technology Symposium, several ELICIT-related papers were presented. One of these won the Best Student Paper Award. Eighteen persons from six countries participated in the post ICCRTS ELICIT User Group meeting. Information about ELICIT, the COI as well as papers related to ELICIT can be found on the CCRP Website. <http://www.dodccrp.org/html4/elicit.html>

ELICIT Program Resources

The initial version of the ELICIT software platform has been and continues to be enhanced. This paper describes two significant new capabilities: the ability to configure organization types and the ability to support agent-based processing that have been added to the web-based version of ELICIT to facilitate constructive experimentation.

Several organizations have also developed and continue to develop tools to automate the extraction of useful data from the detailed transaction logs created by the ELICIT software. In addition, an experimental campaign has been defined to maximize the value of coordinated ELICIT experimentation.

New Configurable Organizations Capability

Motivation For Enhancement

ELICIT has been used to conduct experiments at several research and educational organizations including extensive experiments conducted by the Naval Post Graduate

School Center for Edge Performance. The original release of ELICIT software supported two fixed organizational treatments: Edge and C2 hierarchy.



Figure 1 Edge Organization

The Edge organization, as shown above in Figure 1, was entirely flat and the traditional C2 hierarchy consisted of 4 teams of 4 persons each reporting to a cross team coordinator. See Figure 2 below.

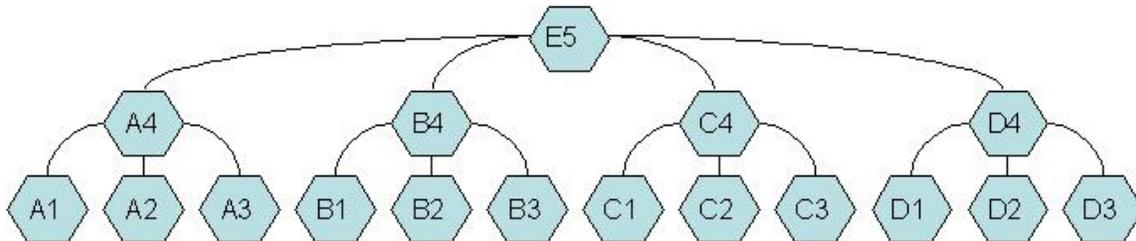


Figure 2 C2 Hierarchy Organization

It was not possible to vary the organization structure or the information sharing actions that were available to different roles in an organization. For example, whether a given participant could send information (a factoid about the experiment scenario) to another specified participant. Feedback from researchers in multiple organizations and countries indicated that it would be helpful to be able to define experiment groups of varying sizes and hierarchy configurations and to support hybrid organization types.

Enhancement Capabilities

The new configurable organization capability provides flexibility in the following areas:

- The number of organization types has been expanded to as many as the researcher wishes to configure. Previously there were only two organization types (Edge and C2)
- The number of participants in an organization is no longer restricted to 17 players for hierarchies
- The number of levels in the hierarchy is now configurable. Previously it was one or three
- The names of the roles (titles) for each person are now configurable. Previously these were hard coded for each of the two defined organization types

- The participants with whom a given participant can Share a factoid is now controlled by a matrix on a participant to participant basis. Previously everyone could always Share with everyone
- The information web sites that a participant can Post to and Pull from are now configurable. Previously there was only one option for each of the two organization types (Edge and C2)

In addition, this new capability has been constructed so that if additional participant actions were added to ELICIT in the future, it would be easy to make them configurable by organization role. If for example, a capability was added for participants to send freeform text messages in the future, it would be easy to make this new capability configurable based on a participants role in an organization so that it could be provided only to team leaders, or only to edge participants, etc.

The ELICIT web-based software platform has also been enhanced to record entries to the MyFactoids list in the transaction log files. This capability means that all participant actions, including moving an item to a personal work area, are now recorded in the transaction log.

New Avenues For Experimentation Supported By Enhancement

The new configurable organizations capability greatly expands the number of experiments that can be performed using ELICIT.

For example, in the original, baseline ELICIT C2 structure, only the cross-team coordinator has access to all four information websites (Who, What, Where and When). The Who, What, Where and When team leaders only had access to their own single respective website. Several researches were interested in seeing just how much expanding this access to each of the four team leaders improved team and overall group performance.

Some researches want to be able to mimic existing organization styles and see how participants performed in their own vs. alternate organization structures. This is now possible. Hybrid organization structures can now be constructed in ELICIT to see which organization elements have the greatest effects.

In addition, it should be pointed out that the factoid distribution continues to be configurable, and could be configured in conjunction with organization roles so that certain roles received better or worse, or more or less information.

The result of this effort is that ELICIT researchers will be able to design and undertake numerous additional experiments. See Appendix A for additional information on the configurable organizations capability.

New Agent-based Processing Capability

Motivation For Enhancement

Numerous researchers have indicated the desirability of adding the ability to support Agent-based processing. That is, to allow software agents to participate in ELICIT experiments. Agent participation can be of two types: Hybrid human and agent participant experiments and agent-only experiments. Arranging for a suitable number of qualified human participants to all be available at one time, is often one of the most challenging and expensive parts of executing a program of experimentation. Frequently all of the recruited participants are not actually available at the scheduled time due to unforeseen circumstances. The ability to have an agent take the place of a missing participant greatly increases scheduling flexibility.

Agent-only experiments can so significantly reduce the cost of running experiments that a significantly greater number of experiments can be run. In addition, theories of behavior and performance could be validated by constructing agents with specific capabilities (personalities) and confirming the resulting outcome by running experiments using agents with those personalities. Agent-based experiments are not intended to entirely replace human trials. Insights gleaned from agent-only trials will need to be replicated with human experiments so that modeling assumptions do not effect final results.

Enhancement Capabilities

The web-based version of ELICIT has been enhanced so that ELICIT agents can be registered for an experiment trial, either in combination with other agents or with humans. Everything else works the same. The humans and agents communicate with the ELICIT 2.2 server software using the same underlying interface and have all the same capabilities so that a human participating in an experiment would not be able to tell if another participant were a human or an agent.

An initial stub agent has been created to validate the interface. The stub agent is able to execute all the actions that a human can, but is not intelligent about how and when it decides to take these actions. An effort is underway to develop more intelligent agents that model human decision making (within the scope of an ELICIT scenario) and human errors. These agents will be able to formulate Identify messages based on awareness and understanding of the factoids to which they have been exposed.

New Avenues For Experimentation Supported By Enhancement

The new agent capability greatly expands the number of experiments that can be run so that more variables can be explored and a sufficient number of runs can be conducted for each experimental condition so that results will be statistically significant.

In addition, the agent capability opens new avenues for exploring theories of behavior and performance. Results gleaned by human participant runs, could be validated by constructing agents with specific traits and confirming the resulting outcome of running experiments using agents with those traits, matched the human results.

Agents could also be used to explore the effect of certain “personality traits” on group performance. For example, how many persons with the “information hoarding” trait does it take to negate a group’s performance? Such experiments could help to quantify and validate rich targets for team training. See Appendix B for more information on the ELICIT agent-based processing capabilities.

The agent capability complements and supplements ELICIT experiments done with human participants. The agent capability is not intended to replace experiments with human subjects, and promising results from experiments with agents will still need to be validated with humans. Replication of the human baseline ELICIT experiments is still a requirements for joining the ELICIT community of interest. Some of the “softer” aspects of ELICIT experimentation, particularly sharing of free-form text information via post-cards or an external chat system are outside the scope of the current agent development effort to create moderately intelligent agents that are configurable. Therefore these avenues of research will remain the purview of human subjects for some time. The lower priority on creating agents that can handle sharing of free-form ELICIT data is due to the difficulty of the task. It is not for lack of interest; as the effects of sharing freeform information (that could represent requests for specific information, sharing of theories about the task situation, or suggestions for modes of self organization) are a very fertile area for ELICIT research. As more subtle aspects of sharing, trust and awareness are studied, there will be an on going tension between the models instantiated in the agent implementations and the designs of the experiments that use them.

Now that we have greatly expanded the universe of possible experiments that can be run with ELICIT, the next logical step is to coordinate these efforts into an overall campaign of experimentation.

Experimentation Campaign

The Command and Control (C2) Community has advanced in its conduct of research to the point of organizing campaigns of experiments oriented toward a common set of objectives (Alberts and Hayes 2005). The idea is for each experiment to both build upon and extend those that have been conducted previously, and for the cumulative new knowledge generated through such experiments to combine and to address important C2 issues through combination.

Despite this progress, however, designing an experimentation campaign can be a challenging endeavor. It is unclear often which key dimensions and variables offer the greatest potential to contribute new knowledge through experimentation, and without some coherent framework for organizing and interrelating the various experiments, planning a sequence of experimentation designs and sessions can devolve into a haphazard activity. Driven largely through our ongoing ELICIT work, we have drawn from the academic and practitioner literatures to develop such a coherent framework for organizing and interrelating the various experiments. This framework is comprised of

four dimensions: 1) *level of analysis*, 2) *C2 approach*, 3) *measure of effectiveness*, and 4) *research method*. We summarize these dimensions in Table 1, and discuss each in turn. To enhance continuity, this discussion is kept to a relatively high level. We elaborate details associated with the experimentation campaign in Appendix C for reference.

Multidimensional Framework

Table 1 Campaign Dimensions (adapted from Nissen 2007)



<i>Level of Analysis</i> ¹	<i>Independent</i> ² (C2 Approach)	<i>Dependent</i> ³ (Measure)	<i>Research</i> ⁴ (Method)
		Performance	Analytical
Social	Organization	Risk	Computational
Cognitive	Process	Agility	Experimental
Information	People	Learning	Field
Physical	Technology	Change	Action

1 Alberts et al. (2001) 2 Leavitt (1965) 3 CCRP workshop (2007) 4 Nissen & Buettner (2004)

12

The level of analysis dimension derives from Alberts et al. (2001), and includes four levels relevant to C2 research: 1) physical, 2) information, 3) cognitive and 4) social. The C2 approach dimension derives from Leavitt (1965), and can be thought fruitfully as involving the independent variables that are selected for analysis via an experiment. Leavitt discusses four key aspects of organizational performance: 1) organization structures, 2) work processes, 3) people and 4) technologies. The measure of effectiveness dimension derives from CCRP (2007), and can be thought fruitfully as involving the dependent variables that are selected for analysis via an experiment. The list of measures can be very long, but we have identified a set of five that capture the most pressing aspects of C2 effectiveness today: 1) performance, 2) risk, 3) agility, 4) learning and 5) change. Research method derives from Nissen and Buettner (2004), and refers to the approach that an experimenter will take to developing new C2 knowledge. This dimension lies somewhat outside of the framework for describing *experimentation* campaigns, for laboratory experimentation represents one of several alternate research methods that can be employed. The five methods associated with this framework are interrelated closely, however, in that they form something of a sequence or life cycle that can be used for planning a research campaign: 1) analytical methods, 2) computational

methods, 3) laboratory experimentation, 4) field research and 5) action research; theorizing, which begins many research campaigns, can be considered as a sixth “method,” but much of the theorizing taking place currently in the C2 domain does not appear to be guided methodologically. Each research method has distinct advantages and disadvantages with respect to others. Each of the four levels of analysis, four C2 approaches, five measures of effectiveness, and five research methods is described in Appendix C.

Campaign Space Visualization

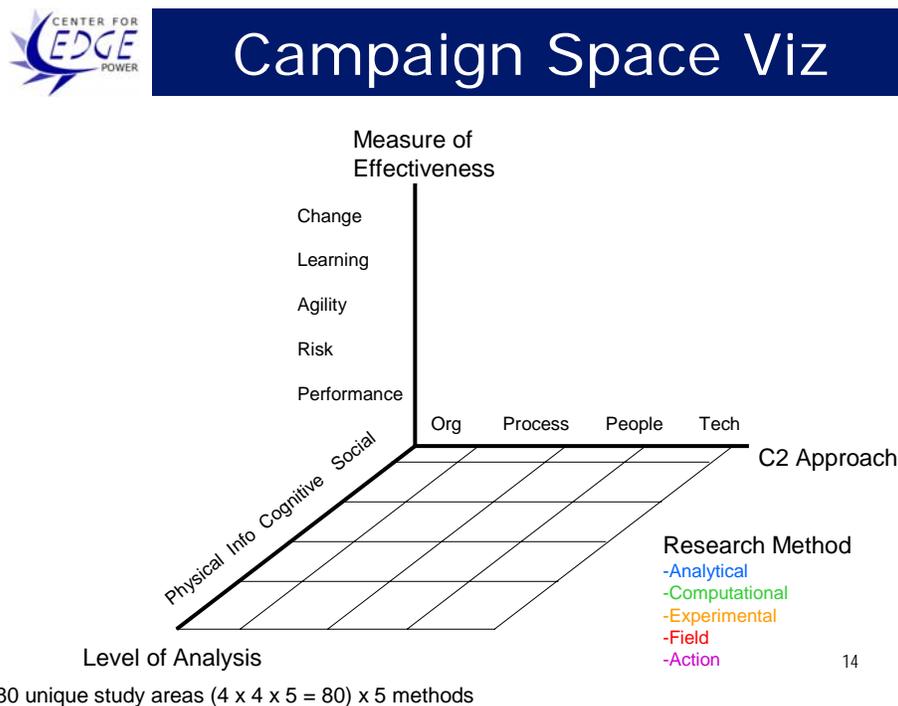


Figure 3 Campaign Space Visualization (adapted from Nissen 2007)

Additionally, we can combine these dimensions in a manner that enables us to visualize their interrelations, and to visualize the campaign space as a whole. Figure 3 depicts the campaign space dimensions as such. Here we have the first three dimensions (i.e., *level of analysis*, *C2 approach*, *measure of effectiveness*) arranged into a three-dimensional coordinate space. Because visualization beyond three dimensions is difficult for most people, we list *research method* outside of this space, and depict the different methods by using different colors. For instance, analytical methods are colored blue, computational methods are green, experimentation methods are orange, field methods are red, and action methods are purple. With this, any particular research project can be viewed in relation to others within a campaign to assess their combined coverage and interrelations in the campaign space. Where all such projects tend to concentrate in one or a small number of areas within this space (e.g., weighted heavily toward new technologies), one could see quickly that other projects would need to be planned to

cover additional areas. Ideally, one would like to see experiments fill this space broadly through a campaign, for it is difficult with research to tell where the high payoff experiments will lie. However, where research results in one or more specific areas prove to have high payoffs in terms of new knowledge generated, one could see quickly that others in these areas might be warranted, but in particular that other research methods (esp. field research) corresponding to these same areas would be in order.

Example Population with Recent Studies

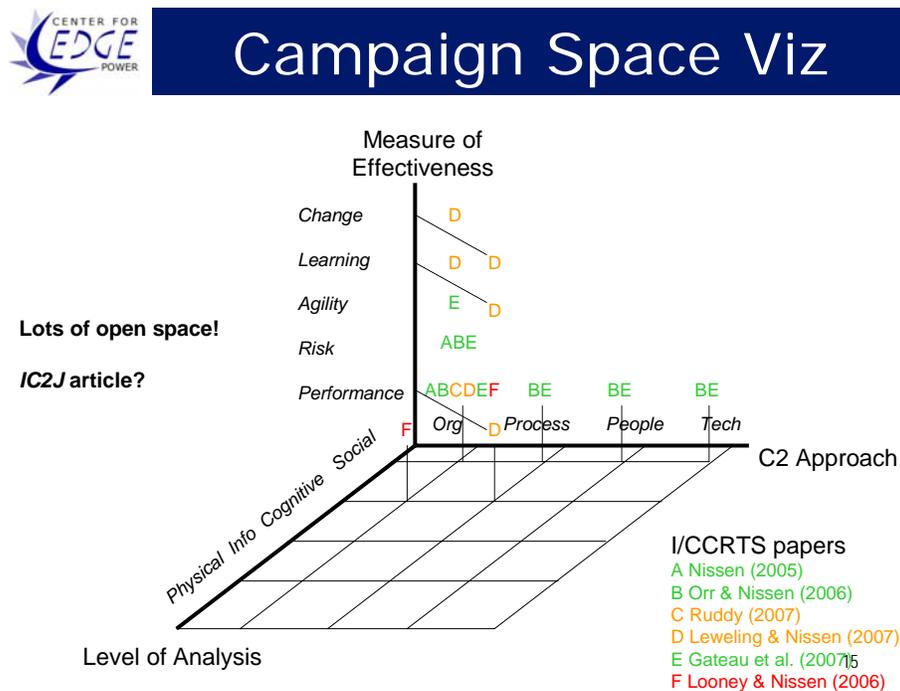


Figure 4 Populated Campaign Space (adapted from Nissen 2007)

In Figure 4 we populate this space with a select set of recent published C2 investigations. (see Nissen 2005, Orr and Nissen 2006, Ruddy 2007, Leweling and Nissen 2007, Gateau et al. 2007, Looney and Nissen 2006). Each study is listed and color coded on the bottom-right of the figure, and a capital letter is placed within the campaign space to depict where such study would be located. For instance, the letter “A” represents the (green) computational method employed in the Nissen (2005) study, and appears at two different coordinates within the space: 1) *social* level of analysis, *organization* C2 approach, and *performance* measure of effectiveness; and 2) *social* level of analysis, *organization* C2 approach, and *risk* measure of effectiveness. Notice that this same study examines two measures of effectiveness: *performance* and *risk*. Letters representing the other studies are plotted in the same manner. Notice that these studies tend to cluster at the *social* level of analysis, *organization* C2 approach, and *performance* measure of effectiveness, but that they span the range of C2 approach and measure of effectiveness. Clearly there are many other areas within this campaign space that would appear to merit

research attention. Being able to visualize such areas represents a strength of this technique.

Self-Organization and Self-Synchronization

Despite the connotations of an “experimentation campaign” that suggest a centrally planned and controlled endeavor, we have just the opposite in mind. Drawing from the same Edge organizing principles (e.g., see Alberts and Hayes 2003) that drive much of this research, we wish instead to establish sufficient goals and conditions for researchers to decide among themselves who will undertake which projects, and in which order, and to synchronize their own activities with those of other researchers to ensure that research projects fill the Campaign Space in a productive and efficient manner.

A clear first step toward establishing such goals and conditions takes place through this article of course, along with the formal and informal discussions likely to ensue, as we lay out the space for researchers to consider as they plan their projects. However, as a community, we will need to do more. Three logical next steps follow. First would be to populate the Campaign Space with studies that have been accomplished to date. Such population could follow the example delineated in the figure above, but would draw from a much broader sample of relevant studies. Second would be to annotate the Campaign Space, or document separately the key conclusions and implications of each project, with the objective of using such metaresearch to identify the most promising avenues for continued research.

Third would be to identify and interact with a relatively large number of researchers, using such interaction to share the ongoing results of this metaresearch (esp. sharing the Campaign Space as it continues to develop, and disseminating the most promising avenues for continued research.), and to track who is doing research in which areas. Fourth would be to continue this pattern of populating the Campaign Space, sharing metaresearch results, and guiding self-organizing and self-synchronizing research projects. Although such self-organization and self-synchronization would be guided by a common Campaign Space, and would be prompted by periodic research sharing and interaction, individual researchers themselves would be responsible for their collective organization and synchronization.

Hence, we would use an Edge approach to organizing Edge research, and we could study our own research organization to glean insights into organizing other kinds of activities and endeavors (e.g., military engagement, disaster relief, coalition operations) via Edge principles. This kind of autoresearch, and the metaresearch noted above, offers great promise, but will require sustained effort over a considerable period of time. We hope that the Campaign Space outlined here will serve as a metaphorical cornerstone for building an impressive knowledge structure both cumulatively and longitudinally.

Conclusion and Suggestions for Future Research

ELICIT is the Experimental Laboratory for Investigating Information-sharing Collaboration and Trust. A project of the Command and Control Research Program, the ELICIT project developed an online multi-user software platform for conducting experiments in information-sharing and trust. The initial version of the software allowed researchers to model and experiment with a limited set of C2 organizations, processes and approaches in a computer-instrumented environment. The ELICIT software has since been enhanced to allow organization type to be configurable, thereby allowing researchers to experiment with a wider variety of C2 organizations, processes and approaches. This facilitates greater use of laboratory experimentation to examine a wider range of theoretical propositions and hypotheses empirically. In particular, the performance of many hybrid and blended organizational forms can be assessed experimentally now via ELICIT, and experimentation can be employed to augment other research methods. For instance, the empirical comparison of multiple, theoretical, archetypal organizational forms by Gateau et al. (2007) can be examined now in the laboratory using ELICIT. This represents a very promising, near-term topic of future research.

In addition, the software has been further enhanced to support software agents as well as human participants, greatly expanding the avenues for research. For instance, validation and exploratory research are needed to examine the relative fidelity and behavior of agent players with respect to their human counterparts, and studies to examine the relative strengths and weaknesses of human and software agents is warranted. In particular, researchers may find it useful to build upon experimentation work by Nissen and Sengupta (2006) on human and software agents in the supply chain, and to adapt their findings regarding human-software agent integration to the C2 domain.

Further, although the introduction and use of ELICIT remain relatively recent events, considerable research has been conducted already using this experimentation platform, and the C2 Research Community is gaining commensurate experience and insight into sound research design. For instance, the research design articulated by Leweling and Nissen (2007) can serve well to guide a diversity of follow-on laboratory experimentation. Building upon such research and experience, we develop a multidimensional campaign for continued experimentation using the ELICIT platform. The campaign is populated with recent studies and guides future researchers toward high-payoff research areas that can be addressed using ELICIT.

In particular, research addressing the cognitive and social levels of analysis appears to be especially promising at this time, for it balances the tremendous effort being expended to study the information and physical levels. Moreover, research addressing the effects of manipulating all four C2 approaches (i.e., organization, process, people, technology)—both individually and in combination—appears to be especially promising at this time also, for it balances the tremendous effort being expended to study purely technological approaches. Examining multiple measures (i.e., in addition to *performance*) offers great merit too, as alternate dependent measures offer tradeoff spaces for leaders and decision makers to consider. Tradeoffs between performance (e.g., in terms of mission speed) and

risk or agility, for instance, are omnipresent in C2, but few studies to date have examined the underlying tension, or have offered practical policy and decision-making guidance. Finally, something of a life cycle of research methods can be seen in the campaign. One may find it productive generally to begin a campaign with analytical methods, and then use computational tools to examine the most promising ideas. Such ideas can be tested further via laboratory experimentation, after which only the most promising approaches can be assessed in the field, and implemented ultimately via action research. Together, the various dimensions—and their interrelations—of the Campaign Space offer excellent potential to guide and integrate a great many, diverse studies into a coherent C2 research stream. This is the idea behind a campaign, and we look forward both to contributing directly to and helping others in this campaign.

References

- Alberts, D.S., Garstka, J.J., Hayes, R.E., and Signori, D.T., *Understanding Information Age Warfare* Washington, DC: CCRP (2001).
- Alberts, D.S. and Hayes, R.E., *Campaigns of Experimentation* Washington, DC: CCRP (2005).
- Alberts, D.S. and Hayes, R.E., *Power to the Edge* Washington, DC: CCRP (2003).
- Alberts, D.S. and Hayes, R.E. *Understanding Command and Control*, Washington, DC: CCRP (2006).
- CCRP, Command & Control Research Program ELICIT Workshop, Vienna, VA (2007).
- Gateau, J.B. Et al. 2007. Hypothesis Testing of Edge Organizations: Modeling the C2 Organization Design Space. *Proceedings International Command and Control Research and Technology Symposium*, Newport, Rhode Island. June 2007.
- Leavitt, H.J. "Applying organizational change in industry: structural, technological and humanistic approaches," in J. March (Ed.), *Handbook of Organizations* Chicago, IL: Rand McNally (1965), pp. 1144-1170.
- Leweling, T.A. and Nissen, M.E., "Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game," *Proceedings International Command & Control Research & Technology Symposium*, Newport, RI (June 2007).
- Mancik, Eric and McCaskill, Josh, *ELICIT: Tracking Networks*, Assembly, May/June 2007 West Point, pp. 30-31.
- Mintzberg, H., *The Structuring of Organizations* Englewood Cliffs, NJ: Prentice-Hall (1979).

Nissen, M.E., "Exploring Edge C2 Approaches: ELICIT and POW-ER Tools," Plenary Presentation, International Command and Control Research and Technology Symposium, Newport, RI (June 2007).

Nissen, M.E., "Hypothesis Testing of Edge Organizations: Specifying Computational C2 Models for Experimentation," *Proceedings International Command & Control Research Symposium*. McLean, VA (2005).

Nissen, M.E. and Buettner, R.R., "Computational Experimentation with the Virtual Design Team: Bridging the Chasm between Laboratory and Field Research in C2," *Proceedings Command and Control Research and Technology Symposium*, San Diego, CA (June 2004).

Nissen, M.E. and Sengupta, K., "Incorporating Software Agents into Supply Chains: Experimental Investigation with a Procurement Task," *MIS Quarterly* 30:1 (2006), pp. 145-166.

Ruddy, M.E., *ELICIT 2.0 Web-based Software Guide*, Parity Communications Inc. under contract to the Naval Post Graduate School Center for Edge Power, Arlington, MA, (2007)

Ruddy, M.E., *Phase 2 - Final Detailed Design for Agent-based Processing v1.1*, Parity Communications Inc. under contract to Evidence Based Research, Chestnut Hill, MA, (2007)

Turban, E. and Aronson, J., *Decision Support Systems and Intelligent Systems* Upper Saddle River, NJ: Prentice-Hall (1998).

Appendix A - ELICIT Configurable Organization Capability Details

ELICIT Organizations are no longer restricted to two hard coded organization types. Now, a variety of organization types can be configured using simple organizationtype.csv text files.

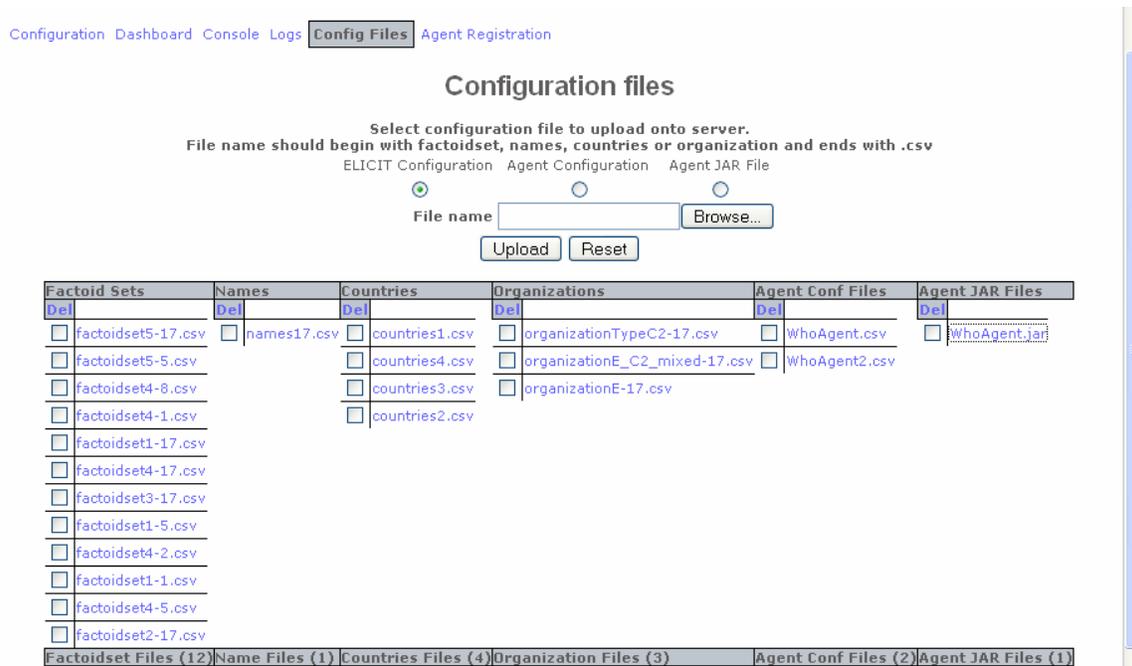


Figure 5 ELICIT Configuration Screen For Loading Organization Type Files.

Figure 5 shows how an organization type.csv file can be loaded into the ELICIT server by a researcher. Support from an information technology specialist is not required.

The file is in .csv (comma-delimited) format, which means that the value in each field is separated with a comma or similar marker. In the ELICIT configuration files, the fields are separated with vertical bar (|). Figure 6 below contains an example organizationtype.csv file.

A key at the top of the file explains data in the file.

```
n|Role|team|Country|1|2|3|...17|Web site1| Web site2| Web site3| Web site4
```

In the actual table that begins on line 5, you see a player number, a team member identity, a country label for that player (if a code of <country*> is supplied, then the nth entry in the country table specified for the experiment trial is used) and a series of numeral 1's with a single 0, which is sequentially arrayed across the grid. If there is a 1 in the first

13th ICCRTS: C2 for Complex Endeavors

B
Who
what
where
when
<end actual table>

Figure 6 The OrganizationC2-17.csv File For The Baseline C2 Organization Scenario

Appendix B - ELICIT Agent-based Processing Capability Details

The ELICIT web-based software has been enhanced so that it can recognize and run agent-based processes either as part of agent-only experiment runs or as part of hybrid human and agent-based participant experiments.

The following steps should be done to develop and deploy a new agent:

- 1) Implement interface AgentIfc or extend AbstractAgent software (create the agent software program)
- 2) Create an agent configuration file (.csv) to contain the parameters driving that agent software
- 3) Deploy agent library jar file and agent configuration file to the ELICIT server using the “Configuration files” page.

Any agent implementation (agent configuration file and agent jar library file) may be uploaded to the ELICIT server on the “Configuration files” page.

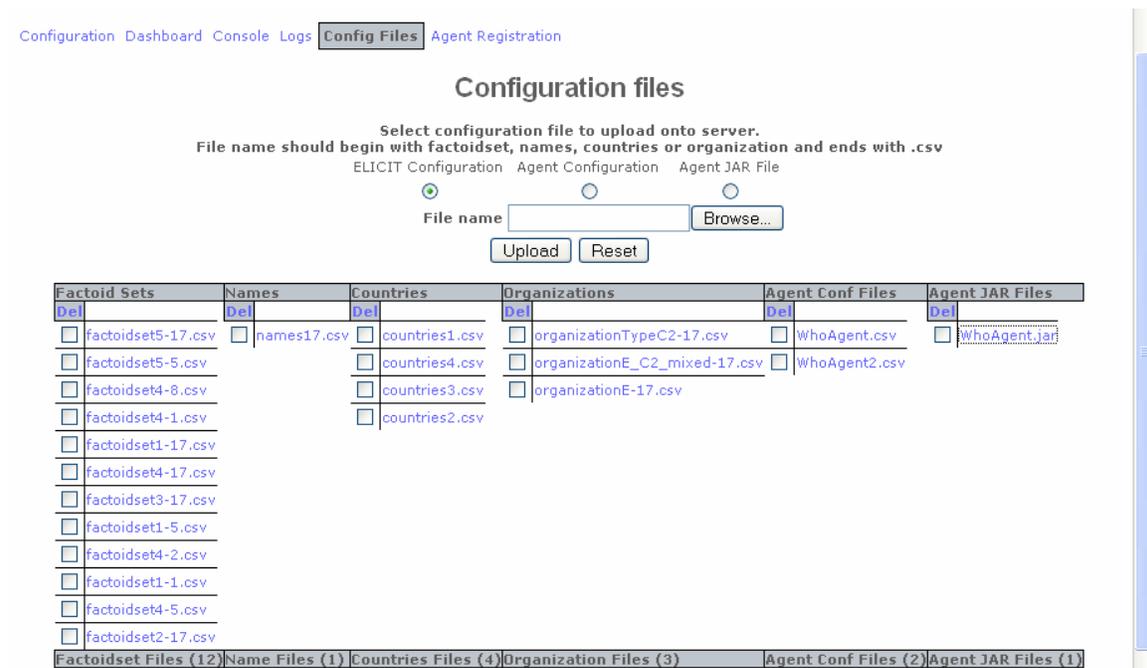


Figure 7 ELICIT Configuration Screen for Loading the Agent-based Processing Files

After the agent software and .csv configuration files have been uploaded, it is possible to add/register a new agent in the ELICIT application so that it can participate in an experiment.

1) Click on the “Agent Registration” option on the Server Moderator Configuration page:

Configuration Dashboard Console Logs Config Files Agent Registration

2) Select the agent configuration file on the “Agent Registration” page:



Figure 8 ELICIT Agent Registration Screen

The dropdown is populated by the values of the names of agent configuration files that were uploaded to the server via the Configuration page. Each agent configuration file references a specific agent library jar file (specific agent software file). A single agent .csv file can be registered multiple times (to represent multiple participants) in an experiment trial.

For example, the WhoAgent2.csv file has the following content:

Agent's actions triggers:

Click Ready button after configured interval after a trial set is started. Action is triggered by receipt of a New Trial Set instruction URL.

Post factoid to who website after configurable delay factor. Action is triggered by receipt of a new factoid in the inbox.

Pull at configurable interval from a specified website (Who).

Share factoid after configured interval after factoid is received in inbox. Share with first participant on Share list.

Move factoid to MyFactoids after configured interval after factoid is received in inbox.

Identify action after configured internal x 10 after factoid is received in inbox. Identify content is hard coded (only three fields are provide).

Once received by the Server via the Agent API, the server treats these actions as if they were generated by a human. Player.

<begin agent configuration parameters>

WhoAgent.jar

net.parityinc.ccrp.web.agent.impl.Agent1

readyIntervalDelay|Time interval to click Ready button|1000

postToWhoSiteDelay|Time interval to post factoid to WHO website|10000

pullFromWhoSiteDelay|Time interval to pull from WHO website|10000

shareWithFirstDelay|Time interval to share with first participant on Share list|10000

moveToMyFactoidsDelay|Time interval to move factoid to MyFactoids|10000

identifyActionDelay|Time interval to identify action|10000

Once an agent has been registered to the server, the agent will appear on the Server dashboard screen. Note that the content of the dashboard fields varies slightly between human and agent participants.

Configuration **Dashboard** Console Logs Config Files Agent Registration

New Trial Set

Del	Num	Host	SessionID	Name	Connect Status	Ready	Client State	Num Identifies	Text of last identify	Roundtrip time	Client
<input type="checkbox"/>		68.162.255.8	16f2d58179d3de3d62b476f94cff7	Mary Player	Online	No	connected	0		243	
<input type="checkbox"/>			1198681139364	WhoAgent2.csv	Online	No	created	0		14	

Participating Players (2)

Figure 9 ELICIT Dashboard Screen

As part of creating and validating this new agent-based capability a stub reference implementation of an agent was developed.

Note, the purpose of this sample stub agent is to demonstrate an agent that can perform the basic actions that a human participant can make. This stub agent merely performs these basic actions. It is not intelligent enough to perform them in an intelligent manner.

Agent's actions trigger:

- Click **Ready** button after configured interval after a trial set is started. Action is triggered by receipt of a New Trial Set instruction URL.
- **Post** factoid to Who website after configurable delay factor. Action is triggered by receipt of a new factoid in the inbox.
- **Pull** at configurable interval from a specified website (Who).
- **Share** factoid after configured interval after factoid is received in inbox. Share with first participant on Share list.
- **Move factoid to MyFactoids** after configured interval after factoid is received in inbox.
- **Identify** action after configured interval after factoid is received in inbox. Identify content is hard coded (only three fields are provide).
- Once received by the Server via the Agent API, the server treats these actions as if they were generated by a human participant.

Additional work is planned to develop a more intelligent sample agent and eventually to provide more guidance to researchers who wish to define new agents (e.g agents with specific personalities or intelligences.) More information on the implementation details of the new agent-based capability is available in the Phase 2 - Final Detailed Design for Agent-based Processing v1.1 document.

Appendix C – Experimentation Campaign Details

In this appendix we elaborate details associated with the experimentation campaign for reference. As in the body of the paper above, the campaign framework is comprised of four dimensions: 1) *level of analysis*, 2) *C2 approach*, 3) *measure of effectiveness*, and 4) *research method*. We summarize these dimensions in Table 1, and discuss each in turn.

Table 2 Campaign Dimensions (adapted from Nissen 2007)



Campaign Dimensions			
<i>Level of Analysis</i> ¹	<i>Independent</i> ² (<i>C2 Approach</i>)	<i>Dependent</i> ³ (<i>Measure</i>)	<i>Research</i> ⁴ (<i>Method</i>)
		Performance	Analytical
Social	Organization	Risk	Computational
Cognitive	Process	Agility	Experimental
Information	People	Learning	Field
Physical	Technology	Change	Action

1 Alberts et al. (2001) 2 Leavitt (1965) 3 CCRP workshop (2007) 4 Nissen & Buettner (2004)

12

Level of analysis. The level of analysis dimension derives from Alberts et al. (2001), and includes four levels relevant to C2 research: 1) physical, 2) information, 3) cognitive and 4) social. First, as implied by the name, the physical level involves the physical hardware, software and equipment associated with the storage, organization and transmission of data and information. This would include, for instance, computers, routers, databases, cables, and wireless transmission and reception equipment. Second, and implied by the name likewise, the information level involves data, information and knowledge that flow through organizations. This would be enabled, for instance, by the kinds of physical hardware, software and equipment noted above, and would include, for instance, for instance, the kinds of data stored in databases, the kinds of information exchanged via documents, and the kinds of knowledge learned through formal courses and practical experience. Both the physical and information levels pertain to inanimate objects.

Third and alternatively, the cognitive level pertains to people, and involves what people feel, know, think and believe. This would include, for instance, individual sense making, situational awareness, search, analysis, decision making, and like cognitive processes. This would be enabled, for instance, by the kinds of data, information and knowledge noted above that flows through the information level, and which is enabled in turn by the kinds of physical hardware, software and equipment noted above in the physical level. Fourth and finally, the social level involves interactions between individual and groups of people, generally viewed within an organizational context. This would include, for instance, interpersonal interactions within dyads, groups, organizations and coalitions, and would be enabled by the kinds of individual sense making, situational awareness, search, analysis, decision making, and like cognitive processes noted above. Notice how each level is enabled, to some extent, by the one below.

C2 approach. The C2 approach dimension derives from Leavitt (1965), and can be thought fruitfully as involving the independent variables that are selected for analysis via an experiment. Leavitt discusses four key aspects of organizational performance: 1) organization structures, 2) work processes, 3) people and 4) technologies. Organization structures involve factors such as the allocation of decision rights and job responsibilities among people in an organization, as well as the division of work and labor, coordination mechanisms, and communication and work routines. Different organization structures (e.g., Machine Bureaucracy, Simple Structure; see Mintzberg 1979) involve different combinations of such factors, and exert dominant effects over organizational performance. Most military organizations, for instance, are very hierarchical, centralized and bureaucratic, and hence reflect the Machine Bureaucracy quite closely. As suggested by the name, work processes involve the arrangement of work tasks accomplished within an organization. This includes task sequencing, timing and organization, as well as other aspects of the work itself. This is what the organization does. People apply their skills in organizations to perform the work tasks. They reflect different education and training levels, backgrounds, cultures, professions, personalities and other factors associated with the diversity of people working in organizations. Finally, technologies involve the kinds of physical, electronic and manual tools used by people to perform organizational work. Most such tools are included in the physical level described above, hence one can see some rough correspondence between these first two dimensions. Leavitt suggests that these four factors combine to outline an integrated design, and that all four should be considered together whenever addressing organizational performance and change. When addressing an approach to C2, all four factors should be considered together, and should complement one another mutually.

Measure of effectiveness. The measure of effectiveness dimension derives from CCRP (2007), and can be thought fruitfully as involving the dependent variables that are selected for analysis via an experiment. The list of measures can be very long, but we have identified a set of five that capture the most pressing aspects of C2 effectiveness today: 1) performance, 2) risk, 3) agility, 4) learning and 5) change. Performance represents the most common measure examined via C2 experimentation, and can be unpacked into multiple submeasures (e.g., speed, accuracy, awareness). Higher levels of performance are preferred generally to lower levels, but management tradeoffs exist

often due to tensions between measures (e.g., one may have to sacrifice speed for accuracy). Understanding the nature of such tensions via experimentation contributes very important knowledge for C2. Risk is viewed by many (e.g., Turban and Aronson 1998) as uncertain events to which probabilities of occurrence can be assigned reliably, but we expand upon this relatively narrow view to include conditions of uncertainty (e.g., uncertain events to which probabilities of occurrence cannot be assigned reliably), equivocality (e.g., contexts in which the important factors of interest are not understood well) and other forms of ignorance regarding future results. Speaking generally, the greater the risk associated with some endeavor, the greater the likelihood that performance will suffer. Hence risk and performance appear to reflect some tension and to present a tradeoff for C2.

Agility is discussed by Alberts and Hayes (2003), and includes six aspects. Robustness refers to the ability of an organization to perform across a range of conditions (e.g., desert, jungle, urban). Resilience refers to the ability of an organization to recover from or adjust easily to misfortune or damage. Responsiveness refers to the ability of an organization to recognize threats and opportunities, and to take the appropriate actions, quickly. Flexibility refers to the ability of an organization to shift between and operate in multiple ways to adjust to changing situations and contexts. Innovation refers to the ability of an organization to learn to do new things, and to learn to do old things in new ways. Adaptivity refers to the ability of an organization to change its C2 organization and process. Speaking generally, agility represents an organization's approach to mitigating risk, and hence is related to performance also. However, agility introduces its own tension with performance, as agile organizations may not perform as well in some circumstances as their more rigid but finely tuned counterparts do. A manager's focus on agility will be contingent upon the nature of the organization's particular circumstances (see Nissen 2005). Learning represents the change in performance over time, and hence can be used to describe such change at any organizational level (e.g., individual, group, organization). Speaking generally, the more uncertain and dynamic an environment is, the more important that learning becomes. Indeed, a manager might be willing to sacrifice some current performance in order to gain additional learning. Hence learning and performance involve some tension and corresponding managerial tradeoffs as well. Finally, change represents the ability to alter one's structure and behavior over time. Like learning, this can be used to describe such change at any organizational level (e.g., individual, group, organization). Speaking generally, the more uncertain and dynamic an environment is, the more important that change becomes. However, change involves disruption to performance inevitably, and hence involves some tension and corresponding managerial tradeoffs as well. One can see that these five measures of effectiveness are interrelated richly. Examination the various tensions and managerial tradeoffs between them represents an important aspect of C2 experimentation.

Research method. Research method derives from Nissen and Buettner (2004), and refers to the approach that an experimenter will take to developing new C2 knowledge. This dimension lies somewhat outside of the framework for describing *experimentation* campaigns, for laboratory experimentation represents one of several alternate research methods that can be employed. The five methods associated with this framework are interrelated closely, however, in that they form something of a sequence or life cycle that

can be used for planning a research campaign: 1) analytical methods, 2) computational methods, 3) laboratory experimentation, 4) field research and 5) action research. Each research method has distinct advantages and disadvantages with respect to others. We consider each in turn.

First, we have analytical methods, which can be performed generally within a researcher's office, with or without the aid of computers or other office equipment. Mathematical modeling, regression analysis and optimization represent three instances of analytical methods. Many research campaigns begin with analytical methods, for they are relatively inexpensive and quick to employ, and research results generated through such methods can provide useful guidance to inform research conducted via other methods (esp. computational methods). For instance, mathematical modeling might suggest a limited set of variables and relations with potential to influence C2 performance, risk and other measures of effectiveness. Such variables and relations could be examined with greater fidelity via computational methods, for instance. However, concepts, variables and relationships are specified abstractly for the most part in analytical methods, and generalizing the results of laboratory experiments to operational organizations, tasks, people and technologies outside the laboratory can be very difficult.

Second, we have computational methods, which can be performed generally with a researcher's office also, but which depend expressly upon computer hardware and software. Indeed, to the extent that a researcher uses computational tools to represent mathematical models, to conduct regression analyses or to solve optimization problems, computational methods and analytical method appear to converge. However, many problems cannot be solved via mathematical models, regression analyses, optimization problems, or other analytical methods, and hence must rely upon other computational methods. Simulation represents a very common instance of computational research method, and simulation models can be run in a controlled manner reflecting laboratory experimentation very closely; such simulation approach is referred to as computational experimentation. As noted above for analytical methods, computational methods are relatively inexpensive and quick to employ also, and research results generated through such methods can provide useful guidance to inform research conducted via other methods (esp. laboratory experimentation). For instance, computational experimentation might suggest a limited set of variables and relations with potential to influence C2 performance, risk and other measures of effectiveness. Such variables and relations could be examined with greater realism via laboratory experimentation, for instance.

Third, we have laboratory experimentation. This is the central research method associated with an experimentation campaign, and involves the study of people and equipment within the laboratory under controlled conditions. Laboratory experimentation enables tremendous control over the environment, and results reflect great reliability and internal validity generally. However, laboratory experimentation tends to be more expensive and require more time than either analytical or computational methods, and generalizing the results of laboratory experiments to operational organizations, tasks, people and technologies outside the laboratory can be difficult often. ELICIT is a tool for laboratory experimentation. Research results generated through such methods can provide useful guidance to inform research conducted via other methods (esp. field

research). For instance, laboratory experimentation might suggest a limited set of variables and relations with potential to influence C2 performance, risk and other measures of effectiveness. Such variables and relations could be examined with greater realism via field research, for instance.

Fourth, we have field research. This involves the study of C2 organizations, work processes, people and technologies in their natural environments (i.e., in the field). A wide variety of field research methods are available, but case studies, ethnographies and field experiments are common in the C2 domain. Field studies have different properties than laboratory experiments do. They enable negligible control over the environment, hence results reflect poor reliability and internal validity generally, and field research tends to be much more expensive and require much more time than laboratory experimentation does. However, generalizing the results of field research to operational organizations, tasks, people and technologies is straightforward generally, and the realism of field research represents a strength of the method. Research results generated through such methods can provide useful guidance to inform research conducted via other methods (esp. action research). For instance, field research might suggest a limited set of variables and relations with potential to influence C2 performance, risk and other measures of effectiveness. Such variables and relations could be examined with greater realism via action research, for instance.

Finally, we have action research. This involves working to make positive changes in operational organizations, tasks, people and technologies, but seeking to learn through systematic study at the same time. Very similar to its field research counterpart, action research methods enable negligible control over the environment, hence results reflect poor reliability and internal validity generally, and action research tends to be much more expensive and require much more time than laboratory experimentation does. However, generalizing the results of action research to operational organizations, tasks, people and technologies is straightforward generally, and the realism of action research is unparalleled. Research results generated through such methods can have immediate and practical impact. This represents a strength of the method.