C2 Agility: Related Hypotheses and Experimental Findings

David S. Alberts
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C2 Agility: Related Hypotheses and Experimental Findings

David S. Alberts
C2 Agility:
Related Hypotheses and Experimental Findings

a tutorial presented at
83rd Military Operations Research Society (MORS) Symposium
June 2015

Dr. David S. Alberts
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Agenda

• C2 Agility
• Hypotheses
• Experiments and Results
• Next Steps
Conceptual Foundation

- **C2 Approach Space**
  Understanding Command and Control (2006)

- **C2 Maturity Levels**
  NATO NEC C2 Maturity Model (2010)

- **Agile C2**
  The Agility Advantage (2011)

- **C2 Agility Experimentation**
  NATO SAS-085 (2013)

This tutorial is based upon the above publications and related presentations.
There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.

Developing the “option space” for Command and Control requires that major differences between possible approaches are identified.

- Centralized v. Decentralized
- Fixed Vertical Stovepipes v. Dynamic Task Organized
- Limited information dissemination (need to know) v. broad dissemination (need to share)

These differences are reflected in the dimensions of the C2 Approach Space (options available)

- Allocation of Decision Rights (within an entity or to the collective)
- Patterns of Interaction
- Distribution of Information
C2 Approach Space

- Distribution of information among entities: broad to none
- Patterns of interaction among entities: unconstrained to tightly constrained
- Allocation of decision rights to the collective: broad to none
The NNEC Feasibility Study used the terms *Coherent* and *Disjointed* rather than Transformed and Stand Alone.
# NATO NEC C2 Approaches

(context is a collection of civil-military entities)

<table>
<thead>
<tr>
<th>C2 Approach</th>
<th>Allocation of Decision Rights to the Collective</th>
<th>Patterns of Interaction Among Participating Entities</th>
<th>Distribution of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge C2</td>
<td>Not Explicit, Self-Allocated (Emergent, Tailored, and Dynamic)</td>
<td>Unlimited As Required</td>
<td>All Available and Relevant Information Accessible</td>
</tr>
<tr>
<td>Collaborative C2</td>
<td>Collaborative Process and Shared Plan</td>
<td>Significant Broad</td>
<td>Additional Information Across Collaborative Areas/Functions</td>
</tr>
<tr>
<td>Coordinated C2</td>
<td>Coordination Process and Linked Plans</td>
<td>Limited and Focused</td>
<td>Additional Information About Coordinated Areas/Functions</td>
</tr>
<tr>
<td>De-Conflictied C2</td>
<td>Establish Constraints</td>
<td>Very Limited Sharply Focused</td>
<td>Additional Information About Constraints and Seams</td>
</tr>
<tr>
<td>Conflicted C2</td>
<td>None</td>
<td>None</td>
<td>Organic Information</td>
</tr>
</tbody>
</table>

Source: NATO SAS-065
Patterns of Interactions: De-conflicted C2

Entity Cluster

- individual
- interaction
- cluster
Patterns of Interactions: Collaborative C2
Patterns of Interactions: Edge C2
What is Agility?

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances.
What is Agility?

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances.

- the concept of Agility does not apply to a stable situation
- external changes (e.g. regime change, permissive to hostile)
- changes to self (e.g. a new coalition partner, loss of capability)
What is Agility?

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances within acceptable bounds of performance (e.g. effectiveness, efficiency, risk).
What is Agility?

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances to respond to an event that would otherwise have adverse consequences.
What is Agility?

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances.

- Take advantage of an opportunity to improve effectiveness and/or efficiency.
- Or reduce risk.
What is Agility?

take actions to effect change or to prevent changes that might otherwise occur

Agility is the capability to successfully effect, cope with and/or exploit changes in circumstances
Components of Agility

• Responsiveness
• Versatility
• Flexibility
• Resilience
• Adaptiveness
• Innovativeness

The contributions of these components to agility are not additive
Responsiveness

- Responsiveness is an essential enabler of Active Agility.

- Responsiveness is a reflection of the timeliness of the intervention(s).

- The efficacy of the intervention is a function of all six of the enablers of agility.
Anatomy of Responsiveness

Measure of Value

Acceptable Value Range

Baseline Performance

Agility Value Added

Actual Performance

Time

Detect  Decide  Act

Restore Acceptable Performance  Desired Effect

Source: Alberts, The Agility Advantage (2011)
Versatility

- Versatility is the passive capability that enables an entity to maintain an acceptable level of performance without having to take action or change oneself.

Screw is able to successfully function under multiple circumstances (different screw drivers)
Flexibility

- *Flexibility* is having more than one way to achieve a desired result.
- Having options becomes important if the preferred way cannot be exercised, does not work given the circumstances, or becomes prohibitively costly.
- In theory, the more options one has, the more likely it is that one will have a good option available whatever the circumstances.
- As the number of options in one’s tool kit increases, the marginal contribution of each additional option gets smaller (the law of diminishing returns).
Resilience

- *Resilience* pertains to changes in circumstances that limit, damage or degrade entity performance.
- Being resilient involves an ability to maintain performance within acceptable bounds despite suffering damage.
- Resilience can be either passive or active or both
  - Being resilient may require that some action being taken (e.g. bring some offline capability on-line) or it may require no action be taken (e.g. existing redundancies provide the protection needed).
  - For example, an appropriately designed network can still provide acceptable services in the event a number of links goes down.
Adaptability

- *Adaptability* refers to making changes to self

- In this case, it is not what one does (choose an alternative course of action) that needs to change, but what one is and how one operates.

- Thus, *adaptability* involves changes to organization, policies, and/or processes.
Innovativeness

- **Innovativeness** involves creating something new
  - e.g. a new way of accomplishing something when current practice does not provide options with adequate performance.
- While *flexibility* refers to having more than one choice, innovativeness adds new ways and means to the toolkit.
- Hence, *Innovativeness* enhances *Flexibility*
Interdependencies

Requisite Flexibility as a function of Resilience

- High Resilience
- Low Resilience
C2 Agility

• There are many ways to accomplish the functions associated with Command and Control

• No one approach to accomplishing the functions associated with command and control fits all missions or situations whether for a single entity or a collection of independent entities (a collective)

• The most appropriate approach will be a function of the endeavor and the prevailing circumstances

• Therefore, Entities (and Collectives) will need to be able to employ more than one approach

• C2 Agility is the ability to appropriately move around in the C2 Approach Space in response to changing missions and circumstances

• Agile C2 systems and processes are required for C2 Agility and to make specific approaches to C2 more agile
This is a most appropriate C2 Approach for this particular set of circumstances
C2 Agility

When circumstances change, a different approach might be more appropriate.

C2 Agility involves recognizing the significant of a change in circumstances, understanding the most appropriate C2 Approach for the circumstance and being able to transition to this approach.
Measuring C2 Agility

• The degree of agility possessed by an entity is a function of its ability to successful operate over an appropriate set of circumstances (Endeavor Space)

• A scalar measure of agility is defined as the area of the region in the Endeavor Space where an entity can successfully operate.

\[ \text{Agility} = \frac{\text{Area of } \bullet}{\text{Area of } \circ} \]
C2 Agility

- C2 Agility = \( f(\text{C2 Approach Agility}, \text{C2 Maneuver Agility}) \)

**C2 Approach Agility** is the area of the region in the Endeavor Space where an entity can operate successfully by employing a given approach to C2.

**C2 Maneuver Agility** is the ability to recognize the C2 approach appropriate for the circumstances and transition to this approach in a timely manner. It is a function of the set of C2 Approaches available to the entity.
## Agility of C2 Maturity Levels

<table>
<thead>
<tr>
<th>C2 Maturity Levels</th>
<th>Contents of C2 Toolkit</th>
<th>C2 Approach Decision Requirement</th>
<th>Transition Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5</td>
<td>Edge C2</td>
<td>Emergent</td>
<td>Edge C2, Collaborative C2, Coordinated C2, De-Conflicted C2</td>
</tr>
<tr>
<td></td>
<td>Collaborative C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coordinated C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4</td>
<td>Collaborative C2</td>
<td>Recognize 3 situations and match to appropriate C2 approach</td>
<td>Collaborative C2, Coordinated C2, De-Conflicted C2</td>
</tr>
<tr>
<td></td>
<td>Coordinated C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3</td>
<td>Coordinated C2</td>
<td>Recognize 2 situations and match to appropriate C2 approach</td>
<td>Coordinated C2, De-Conflicted C2</td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>De-Conflicted C2</td>
<td>N/A</td>
<td>None</td>
</tr>
<tr>
<td>Level 1</td>
<td>Conflicted C2</td>
<td>N/A</td>
<td>None</td>
</tr>
</tbody>
</table>

Adapted from the Alberts, D. S. (2011). Agility Advantage, CCRP
Agenda

• C2 Agility

• Hypotheses

• Experiments and Results

• Next Steps
C2 Agility Hypotheses

H1: Each C2 Approach is located in a distinct region of the C2 Approach Space

H2: No one approach is always the most appropriate
C2 Agility Hypotheses

H3: More network-enabled approaches are more appropriate for Complex Endeavors; while less network-enabled approaches are more appropriate for less complex missions/circumstances
C2 Agility Hypotheses

H4: More network-enabled approaches are more agile (have greater C2 Approach Agility)
C2 Agility Hypotheses

H5: The dimensions of the C2 approach Space are positively correlated with agility
C2 Agility Hypotheses

H6: More network-enabled approaches are better able to maintain their intended positions in the C2 Approach Space

H7: On-diagonal (balanced) approaches are more agile

H8: Increasing C2 Maneuver Agility increases agility
H9: More mature C2 capability is more agile than the C2 Approach Agility of the most network-enabled approach available

H10: Self monitoring is required for C2 Maneuver Agility

H11: The six enablers of agility are collectively exhaustive and thus all instances of observed agility can be traced to one or more of these enablers

H12: Each of these enablers is positively correlated with agility
Agenda

• C2 Agility

• Hypotheses

• Experiments and Results

• Next Steps
C2 Agility Experimentation

- DoD CCRP ELICIT
- SAS-085 Campaign of Experimentation (CAMPX)
- ARL Network Science Research Laboratory
DoD CCRP ELICIT

Experimental Laboratory for the Investigation of Collaboration Information-sharing and Trust

- The U.S. DoD (OASD/NII) Command and Control Research Program (CCRP) sponsored the design and development of the ELICIT platform for experimentation and classroom activities focused on information, cognitive, and social domain phenomena.

- The purpose of ELICIT-related experimentation, teaching, and analysis is to investigate the cognitive and social impacts of C2 approach and organizational structure (e.g. information sharing, trust, shared awareness, and task performance).

- ELICIT features:
  - An instrumented environment
  - Flexibly configurable C2 approaches
  - Supports both person-in-the-loop and software agents
  - Context provided by instructions/procedures/data files
Controllable in ELICIT

Network Characteristics & Performance

Info Sharing & Collaborative Behaviors

Task Difficulty

Shared Information

Quality of Information

Shared Awareness

Quality of Awareness

Shared Understanding

Quality of Understanding

Approach to F&C (C2)

C2 Maturity Levels

Task Performance

Measures of Merit

Individual & Team Characteristics

Quality of Information Sources

Culture

Controllable In ELICIT
# Hierarchy – Edge

**Measures of Effectiveness and Efficiency**

**Results of Human Trials**

<table>
<thead>
<tr>
<th></th>
<th>Average Correctness</th>
<th>Average Timeliness</th>
<th>Average Efficiency</th>
<th>Average Error Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchy</td>
<td>.025</td>
<td>.013</td>
<td>.011</td>
<td>.549</td>
</tr>
<tr>
<td>Edge</td>
<td>.193</td>
<td>.080</td>
<td>.044</td>
<td>.426</td>
</tr>
</tbody>
</table>

*Alberts, The Agility Advantage (2011) Results from 7 matched sets (14 human trials)*
Agility Map for Edge C2
(with an adaptive information sharing policy)

Endeavor Space
with varying Signal-Noise Conditions and Degrees of Network Damage

Mission Requirements

Timeliness

Success
Failure < 10%
Failure > 10%
Failure = 100%

Noise
Normal

Network Damage
None 1 Link 2 Links
High
None
Agility Map for Edge C2
(with an adaptive information sharing policy)

Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments
Comparative Agility Map

Endeavor Space

with varying conditions of signal to noise and with varying requirements for shared situation awareness and response time

Organization Approach Options

- Edge
- Collaborative
- Coordinated
- De-conflicted

Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments
C2 Agility Experimentation

- DoD CCRP ELICIT

- SAS-085 Campaign of Experimentation (CAMPX)

- ARL Network Science Research Laboratory
The method followed is based on the prospective meta-analysis methodology in order to produce a more complete, robust and generalizable set of findings than summarizing multiple independent experiments.
SAS-085 CAMPX Experimental Platforms

- All experimental platforms are constructive agent-based simulations, each of which instantiates at least two C2 Approaches and simulates a variety of circumstances.

- ELICIT: Scenario that finds the Who, What, Where and When of a terrorist attack. There are three variants:
  - ELICIT-IDA (U.S.A.)
  - abELICIT (Portugal)
  - ELICIT-TRUST (U.S.A.): agents are influenced by trust

- IMAGE (Canada): Multi-agency stabilization operation

- WISE (U.K.): Air and maritime support to land operation

- PANOPEA (Italy): Maritime counter-piracy operation
ELICIT-TRUST

- C2 environments will exist in situations where entities do not trust or there is uncertainty with regard to the behavior of others in the Collective
- ELICIT-TRUST implements sharing behavior between nodes based on trust estimate of other agents
- Trust is a function of competence and willingness.
- Trust evolves according to Bayesian models and agents adapt their behaviors based on estimated trust of neighboring entities
- Communication network effects degrade the flow of information
<table>
<thead>
<tr>
<th></th>
<th>ELICIT- IDA</th>
<th>ELICIT-TRUST</th>
<th>abELICIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self</strong></td>
<td>Network damage</td>
<td>Message/Drop rates</td>
<td>Infostructure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>degradation</td>
</tr>
<tr>
<td></td>
<td>Trust</td>
<td></td>
<td>Agent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>performance</td>
</tr>
<tr>
<td></td>
<td>Selfishness</td>
<td></td>
<td>Organisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>disruption</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Challenge</td>
<td></td>
<td>Key information</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>available</td>
</tr>
<tr>
<td></td>
<td>Noise in information</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cognitive complexity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IMAGE

- IMAGE is a complexity comprehension tool augmented with software agents that deliberate and act according to rules that comply as much as possible with N2C2M2 theory.
- The scenario involves multiple organizations that try to secure and stabilize the failing state by using a comprehensive approach.

**Canadian**
- JTF: Joint Task Force
- AAFC: Agriculture Canada
- CIDA: Canadian International Dev. Agency
- DFAIT: Foreign Affair and Int. Trade Canada
- RCMP: Royal Canadian Military Police

**International**
- DWB: Doctor Without Border
- WHO: World Health Organization
- WFP: World Food Program
- Red Cross

**Local**
- Armed forces
- Police
<table>
<thead>
<tr>
<th>C2 Approach</th>
<th>Allocation of Decision Rights to the Collective</th>
<th>Patterns of Interaction among Entities</th>
<th>Distribution of Information among entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicted</td>
<td>Each organization decides of its unit locations and activities</td>
<td>Between units of the same organization</td>
<td>Between units of the same organization</td>
</tr>
<tr>
<td>De-conflicted</td>
<td>Each organization decides on its unit locations and non-conflicting activities</td>
<td>With organizations having collocated units for preventing conflicting activities</td>
<td>Variables shared instantly between organizations having collocated units</td>
</tr>
<tr>
<td>Coordinated</td>
<td>Like in De-Conflicted but interacting activities are considered first with collocated units</td>
<td>With organizations having collocated units for considering interacting activities</td>
<td>Like in De-Conficted + variables shared with 5 non-collocated units (delay: 5 iter)</td>
</tr>
<tr>
<td>Collaborative</td>
<td>All activities and unit locations are decided collectively</td>
<td>With all organizations for deciding unit locations and activities.</td>
<td>Same as coordinated but with any number of units (delay 3 iter.)</td>
</tr>
</tbody>
</table>
The Wargame Infrastructure and Simulation Environment (WISE) is a Land focused C2 model with representation of air and maritime support to Land operations at the system level.

The scenario simulates a failing state that is experiencing internal conflict. The central government has invited a NATO coalition to stabilize the country.

The UK operation represents a brigade size operation with the specific intent of clearing insurgents from a major urban area.

WISE represented degraded conditions within the brigade operational area by varying the quality of battlefield communication.
PANOPEA is a simulator for reproduction of anti-piracy operations and for evaluating the different approaches defined in NEC C2M2.

- PANOPEA reproduces military frigates and helicopters, ground base, cargos, fisherman, yachts traffic and pirates.

- Units are managed by intelligent software agents.
- Ship decision-making capability
- Intelligence DM capability
- Number of pirates
- Weather condition
- Misleading information
The differences among the experimental instantiations of the C2 approaches was investigated and these were found to be insignificant for the purposes of the CoE.

<table>
<thead>
<tr>
<th></th>
<th>ELICIT-IDA (USA)</th>
<th>ELICIT-TRUST (USA)</th>
<th>abELICIT (Portugal)</th>
<th>IMAGE (Canada)</th>
<th>WISE (UK)</th>
<th>PANOPEA (Italy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicted</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>De-Conflicted</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Coordinated</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Collaborative</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Edge</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Not all of the experiments implemented all of the C2 Approaches.
Creating an Endeavour Space

- The Endeavor Spaces were populated by combining all possible values of multiple variables, each one corresponding to an aspect of the situation.

- Heat maps show the progressive degree of challenge of the Endeavour Spaces.
  - Darker shades of orange represent most challenging circumstances.
  - Values were normalized across the experiments.
SAS-085 CAMPX Endeavour Spaces
H1: Each of the NATO C2 Maturity Model approaches is located in a distinct region of the C2 Approach Space
Combined results show that C2 approaches are located in distinct regions of the C2 Approach Space.
No ‘One Size’ Fits All

H2: No one approach to C2 is always the most appropriate

H3: More network-enabled approaches to C2 are more appropriate for more challenging circumstances; however, less network-enabled C2 approaches to C2 are more appropriate for some circumstances
More Network-Enabled = More Agility

H4: More network-enabled approaches to C2 are more agile

- Darker shades of teal correspond to higher levels of mission success (1), lighter ones to failure (0)
- Blank squares represent non-simulated cases
More Network-Enabled = More Agility

De-Conflicted was successful in 27 out of 54 circumstances
Agility Score (IMAGE, De-Conflicted) = 27/54 = 0.50

- Darker shades of teal correspond to higher levels of mission success (1.0), lighter ones to failure (0.0)
- Blank squares represent non-simulated cases
Results suggest that Agility accelerates as C2 approaches become more network-enabled.

The relation between C2 Approach and Agility Score is quadratic ($R^2 = 0.99$).
H5: The dimensions of the C2 Approach Space are positively correlated with agility

- Individually: Agility Score is strongly correlated to each dimension of the C2 Approach Space
- Collectively (multiple regression):

  \[
  \text{Agility Score} = 0.030 + 0.460 \times \text{Allocation of decision rights} \\
  - 0.269 \times \text{Patterns of interaction} \\+ 0.274 \times \text{Distribution of information}
  \]

\[R^2_{\text{ADR}} = 0.965\]
\[R^2_{\text{Pol}} = 0.858\]
\[R^2_{\text{DoI}} = 0.983\]
Location Variations in C2 Approach Space

H6: More network-enabled C2 approaches are better able to maintain their position in the C2 Approach Space

- Only patterns of interaction and distribution of information were affected by circumstances

- The deviation was measured by the spreading, calculated from the area occupied by all circumstances
H6: More network-enabled C2 approaches are better able to maintain their position in the C2 Approach Space.
H7: On-diagonal (balanced) approaches to C2 are more agile

<table>
<thead>
<tr>
<th>C2 Approach</th>
<th>On-Diagonal Group</th>
<th>Off-Diagonal Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average % Maximum Effectiveness</td>
<td>82%</td>
<td>36%</td>
</tr>
<tr>
<td>Average Distance from Diagonal</td>
<td>0.02</td>
<td>0.09</td>
</tr>
</tbody>
</table>
H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted

<table>
<thead>
<tr>
<th>C2 Maturity Levels</th>
<th>Contents of C2 Toolkit</th>
<th>C2 Approach Decision Requirement</th>
<th>Transition Requirements</th>
<th>Region of the Endeavor Space where a collective is successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5</td>
<td>Edge C2</td>
<td>Emergent</td>
<td>Edge C2</td>
<td><img src="image1.png" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Collaborative C2</td>
<td></td>
<td>Collaborative C2</td>
<td></td>
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<tr>
<td></td>
<td>Coordinated C2</td>
<td></td>
<td>Coordinated C2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
</tr>
<tr>
<td>Level 4</td>
<td>Collaborative C2</td>
<td>Recognize 3 situations and match to appropriate C2 approach</td>
<td>Collaborative C2</td>
<td><img src="image2.png" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Coordinated C2</td>
<td></td>
<td>Coordinated C2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
</tr>
<tr>
<td>Level 3</td>
<td>Coordinated C2</td>
<td>Recognize 2 situations and match to appropriate C2 approach</td>
<td>Coordinated C2</td>
<td><img src="image3.png" alt="" /></td>
</tr>
<tr>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
<td>De-Conflicted C2</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>De-Conflicted C2</td>
<td>N/A</td>
<td>None</td>
<td><img src="image4.png" alt="" /></td>
</tr>
<tr>
<td>Level 1</td>
<td>Conflicted C2</td>
<td>N/A</td>
<td>None</td>
<td><img src="image5.png" alt="" /></td>
</tr>
</tbody>
</table>

Adapted from the Alberts, D.S. (2011). Agility Advantage, CCRP

Conflicted | De-Conflicted | Coordinated | Collaborative | Edge
H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted.
C2 Maturity $\rightarrow$ C2 Agility

*Experimental results suggest more an imbricated model than a complementary one*
C2 Agility Experimentation

- DoD CCRP ELICIT
- SAS-085 Campaign of Experimentation (CAMPX)
- ARL Network Science Research Laboratory (NSRL)
A specific C2 Approach is defined in three dimensions
  – allocation of decision rights
  – patterns of interactions
  – distribution of information

The allocation of decision rights is a design parameter of a social network that is a function of organizational structure.

A patterns of interaction is an outcome of a social network and is a function of prescribed or emergent organizational processes.

The distribution of information is a function of policies, processes, and individual propensities.

All of the above are enabled or constrained by capabilities provided by information and communications networks.
A Composite Network is a collection of interdependent networks.

The values of each of the C2 Approach dimensions is the result of the outcomes associated with three interdependent networks (social, information, and communications), each with specific design parameters values, behaviors, and performance.

Thus, C2 experiments should be conceived of and instantiated as multi-genre composite network experiments.
Composite Network Experimentation

• Need to move beyond single genre experiments that represent the capabilities and performance of other networks by parameters
  – e.g. ELICIT will parameter determined communication delays

• ARL NSRL developed an ELICIT-EMANE* integrated environment as a first step in a planned development of a composite network experimentation environment
  – All interactions between social network nodes go through an emulated mobile tactical communications network

• This IOC capability will be enhanced with the introduction of an information network and network monitoring to explore integrated design of composite networks and context-aware network behaviors
Agenda

• C2 Agility

• Hypotheses

• Experiments and Results

• Next Steps
Frontiers of C2 Agility Research

- C2 of Composite Networks
- Cyber Security as a component of integrated design
- Automation and autonomy as a C2 Approach
The objective of this tutorial is to acquaint attendees with the foundational concepts upon which C2 Agility is constructed, the metrics that are associated with C2 Agility, and C2 Agility-related experimentation and results to date.